PERMIAN ECHINODERMS FROM WESTERN AUSTRALIA

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A new study of the Permian echinoderms of Western Australia included field collection and restudy of several earlier collections. Significant morphologic and stratigraphic details are provided about previously described taxa. New taxa are the crinoids: *Neocamptocrinus barrabiddyensis, N. millyitensis, Stomiocrinus merlinleighensis, Neoplatycrinus callytharaensis, N. miamiaensis, Wrightocrinus wooramelensis, Litocrinus pansus, L. protuberans, Lampodosocrinus variabilis, Cosmetocrinus? middalyaensis, Sphenìscocrinus australis, Minilyacrinus williamburyensis, Texacrinus goochensis, T. hardmanensis, T. gascoynensis, Galateacrinus australis, Cymbiocrinus cherrabunensis, Jimbacrinus donnellyensis*, and *Baryschyr? carnarvonensis* and the blastoids *Neoschisma extensum*, and *Rhopaloblastus cuspidus* and the stellaroid *Monaster coleyi*. Echinoid remains are recorded for the first time in the Permian of Western Australia. Ranges of several Carboniferous crinoids are extended into the Permian, including a coelocrinid and pentameric stem-bearing forms. The youngest Palaeozoic crinoids known are described from the Tatarian Hardman Formation of the Canning Basin.

Echinoderms in the Callythara Formation include 16 camerates, 37 inadunates, and 1 flexible among the crinoids, 5 blastoids, and 1 echinoid. Younger Permian strata yielded 3 camerates, 12 inadunates, 1 blastoid, and 1 starfish. Lineages of *Neocamptocrinus, Neoplatycrinus, Texacrinus, Jimbacrinus, Tapinocrinus*, and *Stomiocrinus* are recognised and offer potential for additional correlation of Permian strata throughout Western Australia. ☐ *palaeontology, Crinoids, Permian, Western Australia.*

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Echinoderms from the Permian of Western Australia were first recorded from crinoid stems by Foord (1890) who described them from the Gascoyne River bed and by Etheridge (1903) who reported an endophytic fungal infestation of some crinoid columnals from the northern Carnarvon Basin. Teichert (1949, 1954) and Webster (1987, 1990) on crinoids, Breimer & Macurda (1972) on blastoids and Kesling (1969) on starfish provide the only detailed works on the fauna to date; Teichert (1951) gave a useful summary of the fauna as he knew it then. This paper describes new crinoids and blastoids as well as providing much new information on known species and recording echinoid remains for the first time. Fossil echinoderms are known from the Permian of the Perth, Carnarvon (previously referred to as the Northwest Basin and Canning Basins with the oldest occurring in the Sakmarian to Artinskian of the Carnarvon Basin and the youngest in the Tatarian of the Canning Basin. Echinoderm fossils dealt with herein include a crinoid cup from the Fossil Cliffs Formation of the Perth Basin, and a few crinoid and blastoid specimens from the Noonkanbah and Hardman Formations of the Canning Basin but principally derive from the Carnarvon Basin where the Callytharra Formation has yielded the most prolific echinoderm fauna.

Permian geology and stratigraphy of Western Australia has been detailed through the regional mapping efforts, since the late 1940s, of the Bureau of Mineral Resources and the Geological Survey of Western Australia in the 1:250,000 geological map series of the BMR. These results owe some of their success to earlier reconnaissance work of several people but in the context of Permian palaeontology that of Teichert was most significant. He contributed numerous papers and reports but none more significant than his landmark study (Teichert, 1949) on the crinoid *Calceolispongia* and biostratigraphic utility of its distinctive species. This work provided an intrabasinal biostratigraphic scheme for the Carnarvon Basin which remains virtually unchanged today. Studies of the Ammonoidea (several papers listed in Quilty, 1975) have been used to provide an international correlation. Summaries of the geology and stratigraphy were provided by the

Geological Survey of Western Australia (Playford et al., 1975), for the Carnarvon Basin by Condon (1954, 1967), and for the Canning Basin by Veevers & Wells (1961). We have confined our study to palaeontology and relied heavily upon these earlier works as a framework within which to place our findings. A generalised locality map and stratigraphic columns of the Carnarvon and Canning Basins were given in Webster (1990).

PRESERVATION

At Callytharra Springs most echinoderm material is disarticulated except for microcrinoids, microblastoids, and pleuricolumnal sections of stems. A few exceptions of articulated cups of crinoids and blastoids are known but disarticulated plates of these species are also found associated. Associated but disarticulated cup plates, brachials and columnals of particular species are present on the outcrop indicating minor displacement but definite disaggregation by currents or bioturbation. Distortion and fracturing, resulting from compaction, is most common in large relatively thin ossicles or thinner parts of more robust faunal elements. This is most noticeable on large camerates such as *Neoplatycrinus* and the stem of *Neocamp-tocrinus*, a result of the ease of seeing such features on the larger faunal elements. Careful collecting and microscopic investigation show that this also occurs in smaller elements of the fauna.

To the north, exposures of the Callytharra Formation from the vicinity of Mt Sandiman through Williambury Station and into the Gooch Range show carbonate grainstones with minor marls and shales forming hogback ridges with the formation tilted, usually to the west and eroded. Large pluricolumnals, dominated by *Baryschyr*? *carnarvonensis* sp. nov. up to 10cm long, are common in the lower part of the Callytharra Formation. Articulated crinoid cups and crowns, although rather infrequently found, occur on bedding surfaces. Specimens are exceedingly difficult to extract because they are the same hardness as the enclosing grainstones. Most specimens tend to weather at the same rate as the matrix and solution weathering of ossicles often precludes identification. The articulated crowns, often with proximal stem attached, deny postmortem transportation. Most are considered to have died in situ; the cause of death is not apparent. The matrix shows no graded bedding that could imply debris flows or tempestites, but bioturbation is obvious in some grainstones.

Considerable time walking bedding planes and looking at weathered scree, is required to find the rare good specimen. Rarely, sets of arms and crowns are found weathering from thin interbeds of shale or marl. We suggest that numerous crinoid species are to be found in these northern exposures of the Callytharra Formation with careful and patient collecting.

FAUNAL ANALYSIS

The faunal list of our collection from the Callytharra Formation (Table 1) shows that we found most of the species recorded by Webster (1987) except for *Tapinocrinus macurdai*, *T. ingrami*, *T.* sp., *Actinocrinites* sp. cf. *A. brouweri* and a few of the unidentified camerate and inadunate radials.

The Callytharra fauna contains 16 camerate species, 37 inadunates and 1 flexible. As briefly summarised by Webster (1987), most Permian crinoid faunas worldwide are dominated by inadunates. Only the Timor and possibly Bolivian faunas contain significant camerates and flexibles. The Callytharra fauna is the second most diverse Permian fauna in the world after Timor but the virtual lack of flexibles leads us to suggest that the flexibles could not adapt to the cooler water environment of the Australian Permian.

In this paper 2 camerates and 12 inadunates are added to the faunal list as outlined by Webster (1987). These include three holdover genera, a coelocrinid (*Dorycrinus*), barycrinid indet., and *Cosmetocrinus*, not previously recorded from the Permian (Moore & Teichert, 1978). The youngest possible ancestors are to be found in the Early Carboniferous of North America. The new inadunates include *Minilyacrinus* gen. nov. and new species of *Lampadosocrinus, Texacrinus, Galateacrinus* and *Baryschyr*? not previously recorded in the region. Only *Texacrinus* was previously reported from the Permian. The microcrinoids described are the first described from Australia. *Wrightocrinus, Litocrinus* and Timorechinidae indet. are known from Timor thus strengthening faunal links between the two areas.

The Basleo fauna of Timor is the most diverse Permian crinoid fauna known in the world. It contains 232 species as opposed to the 56 species so far recorded in the Callytharra Formation. Although study of the Timorese collections housed in European museums leads one of us (GDW) to believe that restudy of the inadunates may reduce the number of species recognised it will remain an incredibly diverse fauna. Teichert (1951) con-

	QML757	QML758	QML759	QML760	QML761	757-761
indet. platycrinitid or dichocrinid radial	1		1		1	
Actinocrinites cf. *A. brouweri*						
Platycrinites wrighti				1		
Neoplatycrinus callytharaensis		6	8		1	15
Pleurocrinus? sp. -radials (basals)	25(16)	2		4		
Neocamptocrinus sp.	8	17	32	10	4	14
indet. dichocrinid radials 1-3	17	5	5	6	1	5
indet. camerate radials 1-5	10		6	2		4
Notocatillocrinus callytharaensis (partials)	2(36)	2(1)	(10)	(2)		1(11)
Synbathocrinus campanulatus (partials)	9	3(1)	2(2)			1(2)
Synbathocrinus constrictus (partials)	2(6)	1				(1)
Cydonocrinus cf. *C. tuberculatus* partial	1					
Tapinocrinus macurdai						
Tapinocrinus ingrami						
Tapinocrinus sp.						
Parabursacrinus magnificus (radials)	(150)	(67)	(77)	(23)	1	(86)
Parabursacrinus granulatus radials	15					
Parabursacrinus nefotassiensis radials	16	7	4	1		1
Calceolispongia spinosa basals	10	5(brachs)	11	1		3
Calceolispongia cf. *C. spinosa*						
Calceolispongia digitata basals	10	7	4	6	2	7
Calceolispongiidae sp. indet.						
indet inadunate radials 1-10	45	9	24	5	3	13
indet. flexible radial			1			
Apographiocrinus pumilus brachials	1			2		2
Phosphannulus pluricolumnals	15					
Radials (unidentified)	169	33	35	14		34
Tegmen spines	21	2	15		4	4
Radials with ribs	7			9		
Neocamptocrinus radials	1					
Infrabasal or basal circlet	30	9	12	4		6
Columnals (unidentified)	many	many	many	many	many	many
Barycrinidae? indet. pentameric pluricolumnals	15			3		
Neoschisma verrucosum plates	4			1		
Neoschisma extensum plates	41	3	6	8		7
Notoblastus stellaris plates	18		17			

TABLE 1. Fauna of type section of Callythara Formation west of Callythara Springs on Wooramel River giving specimen numbers from field collections by the authors. Numbers in parentheses refer to partial cups or specific cup plates where both complete and partial cups were found.

sidered the Western Australian fauna closely allied to that of Timor but, with the exception of *Calceolispongia* he regarded the Western Australian fauna as an impoverished Timor fauna without indicating any reason for the impoverishment. We suggest that the Timor fauna lived in a

	Callytharra	Coyrie	Bulgadoo	Cundlego	Quinnanie Sh.	Wandagee	Fossil Cliffs	Noonkanbah	Cherrabun Mbr
Neocamptocrinus millyitensis									x
Neocamptocrinus occidentalis				x					
Neocampto. barrabiddyensis			x						
Stomiocrinus ferruginus						x			
Stomiocrinus merlinleighensis			x						
Texacrinus hardmanensis									x
Texacrinus gascoynensis				x					
Texacrinus goochensis	x								
Skaiocrinus granulosus						x			
Jimbacrinus minilyaensis						x			
Jimbacrinus bostocki				x					
Jimbacrinus donnellyensis			x						
Cymbiocrinus cherrabunensis									x
Trautscholdicrinus sp.							x		
Occiducrinus australis						x			
Rhenocrinidae gen. nov.						x			
Eoindocrinus praecontignatus						x			
Tapinocrinus spinosus						x			
Family and genus indet.						x			
Anechocrinus nalbiaensis					x				

TABLE 2. Lineage chart and stratigraphic distribution of the echinoderm fauna of the post-Callytharra Fmn Permian of WA. Taxa from Teichert (1949) are not included as they were well placed stratigraphically in the original work. Callytharra through Wandagee Fmns are in stratigraphic sequence for the Carnarvon Basin. The Fossil Cliffs Formation of the Perth Basin is temporally equivalent to the Callytharra Fmn. The Noonkanbah Fmn (equivalent to the Coyrie through Wandagee Fmns) and Tatarian Cherrabun Mbr, Hardman Fmn are in the Canning Basin.

warm water environment favourable to a higher carbonate productivity. In contrast the abundant clastic sedimentation of the Western Australian Permian and the type of sediment suggest not only nearer shore, more turbid environments but also cooler water environments with less carbonate production. The cooler water environment of the Permian deposits of Western Australia were recognized by Condon (1967) and Dickins (1978) among others. We consider the echinoderms of the Western Australian Permian to be those that could adapt better to the greater diversity of environments and note that a few are unknown in Timor (*Texacrinus*, *Cosmetocrinus* and the coelocrinid).

The post Callytharra crinoids of Western Australia, following the work of Teichert (1949, 1954), Webster (1990) and this paper, number 3 camerate and 12 inadunate genera. These forms occur mainly in sandstone or shale with rare exceptions such as *Stomiocrinus merlinleighensis* and *Jimbacrinus donnellyensis*. Many occur in clusters with multiple specimens of few species along bedding planes. Many specimens were disaggregated in part indicating postmortem current or scavenger activity. Cross-bedding, scour and fill and ripple marks were observed in these sandstones recording current activity. Bioturbation is evident but not extensively.

Crinoids of the Cherrabun Member, Hardman Formation in the Canning Basin (Table 2) are among the youngest Palaeozoic crinoids known. The age of this horizon, which also yielded the ammonoid *Cyclolobus persulcatus* Rothpletz, 1892, is discussed by Glenister et al. (1990) as Dzhulfian (i.e. within the Tatarian of the European scale). All three species represent lineages common in the Carboniferous of North America. *Cymbiocrinus* is known from the Permian of Thailand (Webster & Jell, in prep.); *Neocamptocrinus* is known only from Australia (Willink, 1980; Webster, 1990; herein).

LINEAGES

Teichert (1951) considered that only one crinoid showed a lineage of stratigraphic utility in Western Australia. Based on knowledge at the time his view was correct. However, the added information from the Callytharra and younger fauna reveals several parallel lineages; some may have biostratigraphic utility through Western Australia, the rest of Australia and even to Timor and India. The *Calceolispongia* lineage detailed by Teichert (1949) remains the most useful for Western Australia but it also needs revision in the light of extensive new collections and its potential for correlation in the Canning Basin has yet to be addressed.

Other lineages that we recognise in Western

Australia (Table 2) are species within each of *Neocamptocrinus, Neoplatycrinus, Texacrinus, Jimbacrinus, Tapinocrinus* and *Stomiocrinus*. Although these are considered independently it should be noted that *Neocamptocrinus, Neoplatycrinus* and *Calceolispongia* occur together at most horizons in the Permian of Western Australia suggesting that they needed similar living conditions.

Stems of *Neocamptocrinus* are found in most horizons with marine fossils from the Callytharra to the Hardman Formations. They have not been studied in detail. Specimens that we have observed show greatest size in the Wandagee Formation (Artinskian) (Fig. 3M,N). Cups, thecae and crowns of *Neocamptocrinus* are uncommon. They are known from the Bulgadoo Shale *N. barrabiddyensis* sp. nov., from the Cundlego Formation, *N. occidentalis*, and from the Hardman Formation, *N. millyitensis*. These three species are considered an evolutionary lineage with *N. occidentalis* evolving from *N. barrabiddyensis* by elongation of the cup with nearly vertical walls distally. In turn, *N. millyitensis* evolved from *N. occidentalis* with a more flattened basal circlet, reduction in the number of plates in the anal series above the primanal and modification of the ornament on tegmen plates. Webster (1990) discussed the relationship of *N. occidentalis* and *N.* n. sp. (=*N. millyitensis*) with eastern Australian species (Willink,1980).

Stomiocrinus merlinleighensis in the Bulgadoo Formation could be the ancestor of *S. ferruginus* in the Wandagee Formation by enlargement, modification of the arms by shortening and thickening the brachials and reduction of the relative size of the orals. Timor species of *Stomiocrinus* are probably derived from *S. merlinleighensis* by modification of oral plates and flattening of the tegmen. *Stomiocrinus* is unknown in eastern Australia.

Evolution of *Neoplatycrinus miamiaensis* from *N. callytharraensis* by modification of the ornament from one large prominent node to several large nodes and probably flattening of the basal circlet forming a low bowl-shaped cup. The "twist" nodals and internodals currently assigned to *Platycrinites/Neoplatycrinus* spp. and commonly found associated with the disarticulated plates of *Neoplatycrinus* probably belong to the genus. Unfortunately they were probably static in evolution during the Early Permian and show no significant differences or evolutionary trends. Although not reported, "twist" columnals are present in the Oxtrack Formation of the Cracow area, Queensland. Additional study of the platycrinid columnals of Australia is needed to fully evaluate their stratigraphic potential.

The tapinocrinids are known from Western Australia and Timor. In Western Australia, *Tapinocrinus macurdai* and *T. ingrami* are known from the Callytherra Formation with the former the likely ancestor of *T. spinosus* from the Wandagee Formation and Basleo fauna of Timor. Development of *T. spinosus* was by flattening of the cup into a disc shape, enlargement of the radials into a blunt spine and loss of granular ornament. Although the spine did not develop, *T. timoricus* also lost the ornament and developed a discoid cup. There is no record of *Tapinocrinus* in eastern Australia.

The texacrinids are represented in Western Australia by four species starting with *T. goochensis* in the Callytharra Formation followed by the more robust *T. gascoynensis* in the Cundlego or Wandagee Formation. No further form of this heavier stock is known. *Skaiocrinus granulosus* is a more elongate form with or without slightly peneplenary radial facets and pinnules with longitudinal ridges. The youngest form *T. hardmanensis* is a slender elongate form which may have evolved through *T. goochensis* from the same stock as *S. granulosus*. Texacrinids are unknown in eastern Australia.

Teichert (1949) considered the origin of *Calceolispongia* to be uncertain but perhaps derived from the Cromyocrinidae. Moore *et al.* (in Moore & Teichert, 1978) suggested that the Calceolispongidae were derived through the Cymbiocrinidae or Ampelocrinidae. We consider the Cymbiocrinidae line to be most likely based on the bowl-shaped cup, large single anal and cuneate arms. The lineage of *Jimbacrinus* is not as clear as that of *Calceolispongia* but may include a sequence from Calceolispongidae? sp. (Webster, 1987) from the Callytharra Formation to *J. donnellyensis* in the Bulgadoo Shale to *J. bostocki* Teichert, 1954 in the Cundlego Formation to *J. minilyaensis* Webster, 1990 in the Wandagee Formation and possibly to *Cymbiocrinus cherrabunensis* in the Hardman Formation.

Webster (1987) noted the resemblance of Calceolispongidae? sp. to the calceolispongids but considered differences in the lack of bulbous basals and presence of an isotomous branching on the third brachial in one ray. If the branching had been on the second brachial the specimen would have been assigned to *Cymbiocrinus*. Calceolispongidae? sp. probably derived from the same ancestor as *Calceolispongia*. *J. donnellyen-*

sis may have evolved from Calceolispongidae? sp. by thickening of the basals and loss of arm branching. In turn *J. bostocki* evolved by development of the spines on the bulbous basals whereas *J. minilyaensis* has a reduction in the bulbous basals, possibly representing a different lineage from Calceolispongidae? sp. *Cymbiocrinus cherrabunensis* is related to the calceolispongids mostly by the bulbous basals; the arm branching pattern, however, is not typical of that family.

The second largest Permian crinoid fauna of the Carnarvon Basin occurs in the Wandagee Formation in the east limb of a syncline on the north bank of the Minilya River, approximately 10km westnorthwest of Wandagee Homestead. This locality is the type locality for several species of *Calceolispongia* (Teichert,1949) and other crinoids (Webster,1990). Some confusion about the stratigraphy has resulted from nomenclatural changes. Teichert (1949) considered the Wandagee Formation to include the unit later named the Quinnanie Shale. Thus some of his material is reported as from the upper Wandagee on locality information at the University of Western Australia when it is actually from the lower Wandagee Formation as defined by Condon (1967) (see Material section under *Occiducrinus australis* and *Skaiocrinus granulosus* (herein; Webster,1990).

There has also been some confusion about the locality. Webster (1990), in citing locality data from the University of Western Australia, listed the locality as east of Coolkilya Pool. Teichert (pers. comm. 1990 to GDW) corrected this to west of Coolkilya Pool as shown on the Winning Pool-Minilya 1:250 000 Geological map (sheet SG50-13, 49-16, 1984). When we stopped at Wandagee Homestead the directions we received to Coolkilya Pool took us further west than the location shown on maps. It is obvious, when on the site, that the size and location of the pool or pools along the river bed shift with scour and fill during major runoff and evaporation and infiltration during subsequent dry seasons. Coolkilya Pool as designated on the map and as referred to by the locals are not the same. Teichert apparently used the local designation in his original field locations and recognized they differed when trying to reconcile the Bureau of Mineral Resources map locations.

In the base of the Wandagee Formation as defined by Condon (1967) *Occiducrinus australis, Eoindocrinus praecontignatus, Calceolispongia abundans*, and *Neocamptocrinus* sp. occur along the same bedding surface. *Tapinocrinus spinosus, Skaiocrinus granulosus* and *Jimbacrinus minilyaensis* occur at or close to the same horizon. *Stomiocrinus ferruginus* may also be from the equivalent horizon along the Lyndon River to the north. Several species of *Calceolispongia* occur at higher levels in the Wandagee Formation as described by Teichert (1949).

AGE AND CORRELATION

Discussion of the age and correlation of the Callythara Formation at its type section was given by Webster (1987). We accept the late Sakmarian age for the base of the Callytharra Formation based on ammonoids (Glenister & Furnish, 1961). New taxa reported herein do not alter Webster's (1987) interpretation that the crinoids suggest a slightly younger age of early Artinskian for the Callytharra Formation. The Sakmarian-Artinskian boundary may be within the lower part of the Callytharra Formation.

Notiocatillocrinus callytharraensis, Synbathocrinus constrictus, Neoplatycrinus callytharraensis and *Neocamptocrinus* sp. in the Callytharra Formation throughout the Carnarvon Basin suggests a similar age for the unit over this extent. Correlation of the Callytharra Formation with the Fossil Cliffs Formation of the Perth Basin, and Nura Nura Member of the Poole Sandstone in the Canning Basin were discussed by Teichert (1951) and Condon (1967). Webster (1987) discussed the crinoid correlation of the Callytharra Formation with that of eastern Australian faunas reported by McKellar (1969) and Willink (1978). The late Sakmarian-early Artinskian limestone interval in the basins of Western Australia, in the Oxtrack Formation in Queensland, and the Berriedale Limestone and limestone in the Crinoidal Zone of Tasmania represent a major sea level rise and change to warmer conditions in the Australian part of the Tethyan equivalent to the Sterlitamak and possibly Birshevian cycles (Ross & Ross,1985).

Correlation with the Permian crinoids of Timor remains somewhat of a problem. The crinoid bearing Maubisse Formation limestones of northern Timor were interpreted as reefs and thought to have been thrust onto the autochthonous non-crinoidal Permian strata of southern Timor (Audley-Charles,1965,1968). He considered the Timor Permian deposits to have formed in a trough to the northwest of Australia. Charlton (1989) suggested that the northern part of Timor was allochthonous but thought much of the struc-

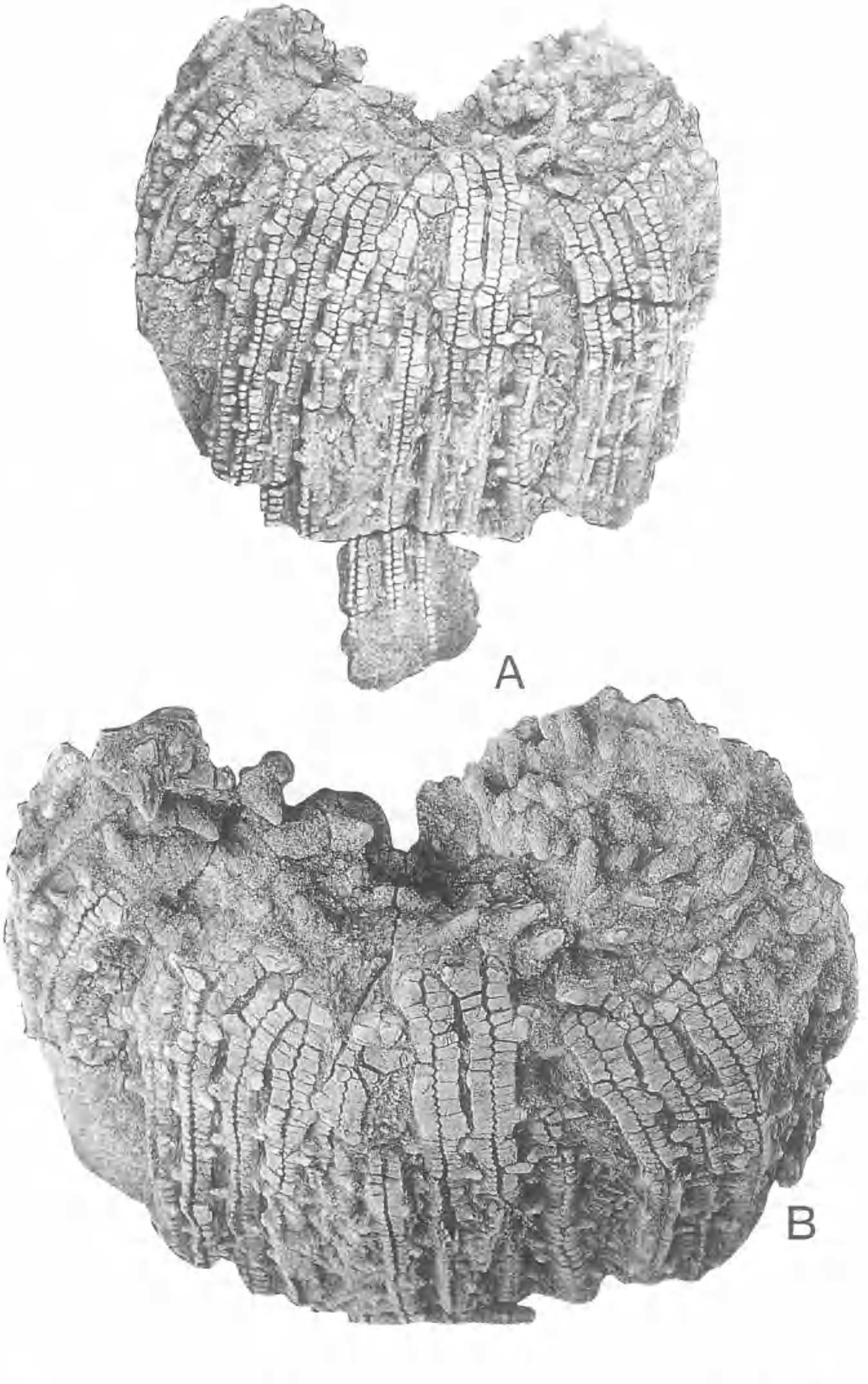


FIG. 1. Coelocrinid indet. QMF21428. A, lateral view showing set of arms with distal part of spinose anal tube at upper right, ×1. B, incurved distal parts of flattened arms and spinose anal tube, ×1.6.

tural complexity was best explained by wrench faulting, not by vertical movements as postulated by Chamalaun and Grady (1978). All of these interpretations agree that the Permian deposits of Timor were formed in and along the distal side of a trough that was part of the Australian block as proposed by Hamilton (1979).

The crinoid bearing Maubisse Formation would have been the most distal deposits, an unknown distance, but perhaps as much as 1000km northwest of the Canning and Carnarvon Basins. Plate reconstructions of the Permian (Zonenshain, Kuzim and Kononov, 1985, among others) position Australia along the eastern part of Gondwanaland. The Carnarvon and Canning Basins would have been between 50° S and 40°S. Timor would have been at approximately 25°–30°S. The Timor faunas were considered Late Permian on reports of fusulinids at Amarassi (Schubert, 1915) and cephalopods at Basleo (Wanner, 1931; Gerth, 1950). Haniel (1915) interpreted the cephalopods as middle Permian, on the Early to Late Permian boundary. Brachiopods (Broili, 1916) and corals (Gerth, 1921) indicated a Permian age but did not specify Early or Late, whereas C. Wanner (1922) placed an Early Permian age on the gastropods and bivalves. The echinoderms were interpreted as Carboniferous (Bather, 1914; Springer, 1920, 1924), in contrast to middle Permian (Wanner, 1924a) and Late Permian (Wanner, 1931).

The lack of stratigraphic control of the numerous crinoid and blastoid localities from Timor has been recognized for many years (Audley Charles, 1965; Glenister & Furnish, 1987; among others). Some cephalopod reports with and without stratigraphic control at a few localities include Sakmarian from Somohole, Artinskian from Bitauni, and Late Permian from Amarassi and Basleo (Glenister & Furnish, 1987). Grant (1976) considered the Bitauni brachiopods to be of Artinskian age. Sections with stratigraphic control have yielded brachiopods from the Chiddruan Maubisse Formation near Kasliu Village, West Timor (Archbold & Bird, 1989) and from the late Sakmarian Khali and Bisnain Members of the Maubisse Formation near Bisnain Village, West Timor (Archbold & Barkham, 1989). The Bisnain brachiopods were correlated with the Callythara Formation by Archbold & Barkham (1989). Artinskian conodonts were recovered from matrix materials and *in situ* limestone blocks collected on early expeditions to Timor (Boogaard, 1987). Thus Timor Permian strata is thought to range from Sakmarian to Amarassian age. Wanner (1931) reported that 90% of Timor crinoids and 75% of all other Permian fossils of Timor are from the Basleo area. It is the age of the Basleo fossils which we consider to be the most problematic because a Late Permian cephalopod has been reported by Glenister and Furnish (1987) from the area. The stratigraphic relationship of the cephalopod and crinoids is unknown.

International correlation based on the crinoids and blastoids suggests an Early Permian age, probably Artinskian or Roadian for the Basleo echinoderms. The Basleo crinoids and blastoids correlate best with Artinskian faunas from the Callythara Formation (12 of the same genera, 3 species; 2 species with affinities and 3 genera with close affinities to Timor genera), the Wandagee Formation (4 of the same genera, 1 species) and the Sarginsk Horizon of the Urals (15 genera). There are few genera and no species in common with the Early Permian of Texas (3 genera), Nevada (7 genera), and Bolivia (2 genus). Few genera and no species are common to the Upper Permian of Russia (1 genus), Sicily (5 genera), Western Australia (1 genus), and eastern Australia (2 genera). These data have been compiled from crinoid occurrences indexed in Bassler & Moody (1943), Webster (1973, 1977, 1986, 1988), and unpublished data.

Until the structure and stratigraphy of the Basleo area are fully understood we consider the echinoderm fauna to be Early Permian recognizing that part of the fauna could be Late Permian based on the cephalopod reported by Glenister & Furnish (1987).

SYSTEMATIC PALAEONTOLOGY

Crinoid terminology follows Ubaghs et al. (in Moore & Teichert, 1978), with columnal patterns after Webster (1974). Blastoid terminology is from Beaver et al. (in Moore, 1967).

Material collected by us during July 1991 came from localities entered in the Queensland Museum Locality Register (QML), and is curated in the Queensland Museum Palaeontological Collection (QMF). Other collections referred to are indicated by the following prefixes: Commonwealth Palaeontological Collection, Bureau of Mineral Resources, Canberra (CPC), Museum of Victoria, Melbourne (NMVP); Western Australian Museum, Perth (UWAF) and Department of Geology, University of Western Australia, Perth (UWAF).

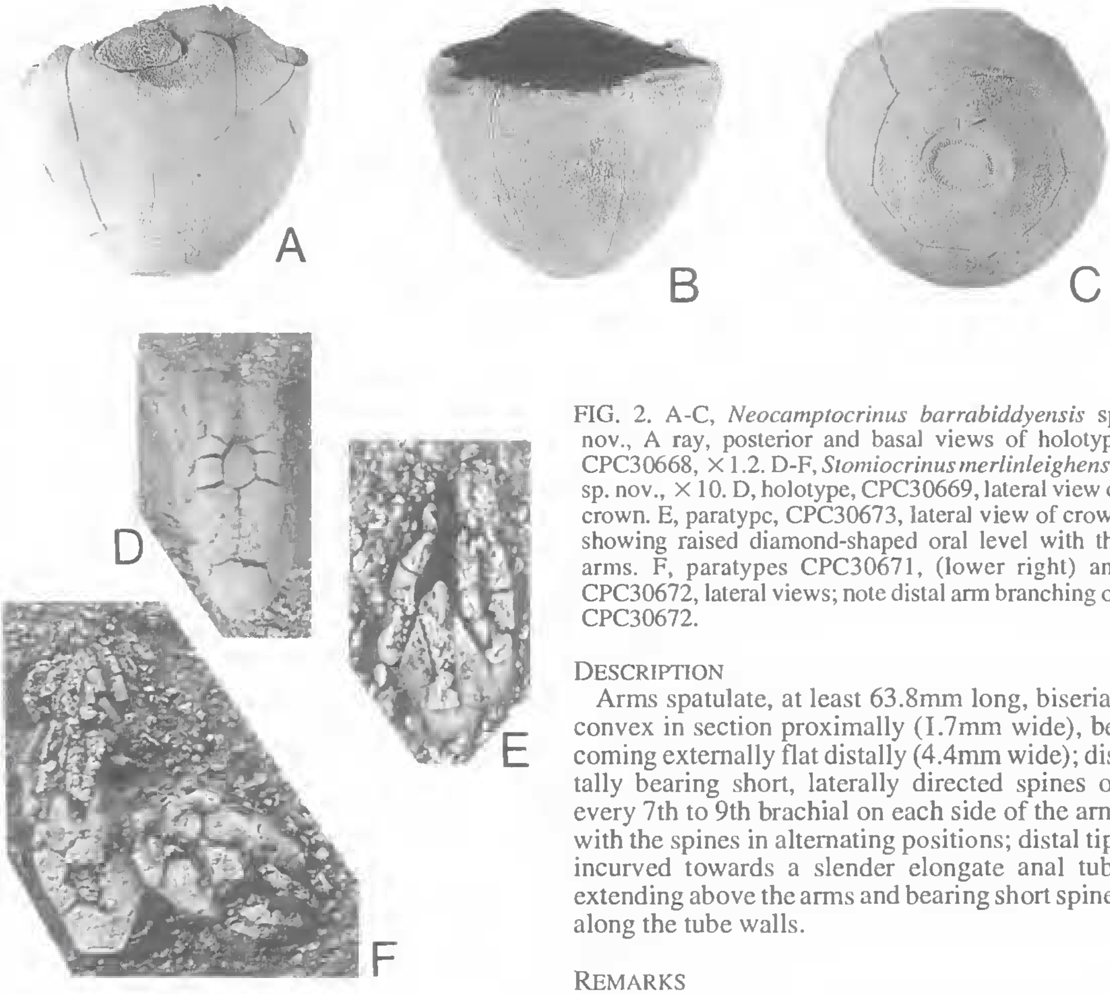


FIG. 2. A-C, *Neocamptocrinus barrabiddyensis* sp. nov., A ray, posterior and basal views of holotype CPC30668, ×1.2. D-F, *Stomiocrinus merlinleighensis* sp. nov., ×10. D, holotype, CPC30669, lateral view of crown. E, paratype, CPC30673, lateral view of crown showing raised diamond-shaped oral level with the arms. F, paratypes CPC30671, (lower right) and CPC30672, lateral views; note distal arm branching on CPC30672.

Subclass CAMERATA Wachsmuth & Springer, 1885
Order MONOBATHRIDA Moore & Laudon, 1943
Suborder COMPSOCRININA Ubaghs, 1978
Superfamily CARPOCRINOIDEA de Koninck & Le Hon, 1854
Family COELOCRINIDAE Bather, 1899

Coelocrinid? indet
(Fig.1)

MATERIAL
QMF21428, a large, weathered, partial set of arms with anal tube, found in three pieces, two of which fitted together, from the middle Callytharra Formation in the eastern line of the Gooch Range south of Carnarvon-Williambury Station road, GR922549 Gooch Range 1: 100,000 topographical sheet (no. 1850), 1974 edition.

DESCRIPTION
Arms spatulate, at least 63.8mm long, biserial, convex in section proximally (1.7mm wide), becoming externally flat distally (4.4mm wide); distally bearing short, laterally directed spines on every 7th to 9th brachial on each side of the arm, with the spines in alternating positions; distal tips incurved towards a slender elongate anal tube extending above the arms and bearing short spines along the tube walls.

REMARKS
This specimen bears remarkable similarity to the illustration (Wachsmuth & Springer, 1897, pl. 42, fig. 5) of *Dorycrinus cornigerus* (Hall, 1858). Anal tube spines of *D. cornigerus* are longer, extending beyond the arms when enclosed. Long spatulate arms are known in several genera of the Batocrinidae and Coelocrinidae (Wachsmuth & Springer, 1897); however, only those of *D. cornigerus* have short laterally directed spines along the sides of the arms. Thus we questionably refer the specimen to the Coelocrinidae.

This is the first Permian report of the otherwise Middle Devonian to Early Mississippian European and North American family (Moore & Teichert, 1978). Other camerates, such as *Actinocrinites*, *Pleurocrinus* and *Camptocrinus*, initially restricted to Early Carboniferous strata of Europe and North America were discovered in the Permian of Timor (Wanner, 1916, 1924a). Thus, a possible coelocrinid in the Permian of Western Australia adds to the list of camerate holdovers lacking a Late Carboniferous record.

Superfamily HEXACRINITOIDEA Wachsmuth & Springer, 1885

Family DICHOCRINIDAE Miller, 1889

Subfamily CAMPTOCRININAE Broadhead, 1981

Neocamptocrinus Willink, 1980

TYPE SPECIES

Neocamptocrinus bundanoonensis Willink,1980, from the Kazanian Berry Formation, New South Wales; by original designation.

REMARKS

Willink (1980) recognised *Neocamptocrinus* on the inflated tegmen and a column that is elliptical throughout its length instead of round adjacent to the cup as is *Camptocrinus*. Carboniferous and Permian camptocrinid columns show that the elliptical shape is similar in both, that is nearly round, but definitely slightly elliptical, adjacent to the cup becoming progressively elliptical in a few centimetres distally and remaining elliptical throughout the remainder of the known column. The long axis of the columnal attains its greatest size in the Permian of Western Australia (Fig. 3M,N). Cups assigned by Willink (1980), Webster, (1990) and herein show an evolutionary and stratigraphic record of potential value for the Permian of Australia and Timor. We question the degree of inflation of the tegmen as a generic feature; however, for convenience we apply the name to these Permian forms including *Camptocrinus* cf. *C. indoaust-ralicus* Wanner (Webster,1987:102, fig. 5J-M).

Columnals of *Neocamptocrinus* are common in many parts of the Permian of Western Australia (Webster, 1987, 1990; herein). Even proximal, nearly circular columnals are easily recognised by the distinctive, off centre, axial canal and unequal length of culmina on the opposing long sides of the articulum. Additional study of *Neocamptocrinus* columnals in Western Australia is necessary to determine their strat-igraphic value. Columnals of *Neocamptocrinus* sp. are present in the Callytharra Formation at all localities we collected. No cups were found, but the radials listed as indeterminate camerate radial 4 and 5 by Webster (1987) probably belong to a new species of *Neocamptocrinus*.

Neocamptocrinus barrabiddyensis sp. nov. (Fig. 2A-C)

ETYMOLOGY

For Barrabiddy Creek.

MATERIAL

Holotype CPC30668, Bulgadoo Shale, east limb of Barrabiddy Anticline, Barrabiddy Paddock, 1/4 mile south of mill.

DIAGNOSIS

Radial notches relatively narrow; radials more expansive.

DESCRIPTION

Cup bowl-shaped, wider (29.1mm) than high (21.8mm), base truncated, widest at base of radial facets, sutures flush, no ornamentation. BB 2, suture faint, 5.6mm wide, 5.5mm high, upflared, slightly concave walls. RR 5, longer (19.4mm) than wide (16.0mm), gently convex transversely, convexo-concave longitudinally. Radial facets angustary, c. 2/3 radial width; transverse ridge elevated, with coarse ridges normal to ridge length; brachial canal circular in section; muscle fields elliptical, long axis subparallel to transverse ridge, moderately impressed; ambulacral groove narrow, sloping inward. Anal longer (19.6mm) than wide (11.3mm), narrower than and in line with radials. Columnal facet elliptical, 8.7mm long, 63mm wide, impressed; articulum narrow; culmen coarse, cog-like, areola wide, flat. Stem and arms unknown.

REMARKS

This robust cup was weathered out of red claystone containing abundant disarticulated plates of *Calceolispongia* cf. *barrabiddyensis*. It has narrower radial notches, radials that distally expand transversely at a greater rate and lower radial facets than *N. occidentalis* Webster, 1987 or *N. millyitensis* sp. nov. These two species probably evolved from *N. barrabiddyensis*

Neocamptocrinus millyitensis sp. nov. (Fig. 3A-L)

Neocamptocrinus sp. nov. Webster, 1990:57, pl. 1, figs 7-11.

ETYMOLOGY

For the Millyit Range.

MATERIAL

Holotype CPC27054, paratypes CPC27455-27457 from the Millyit Range. Other material, QMF21420-

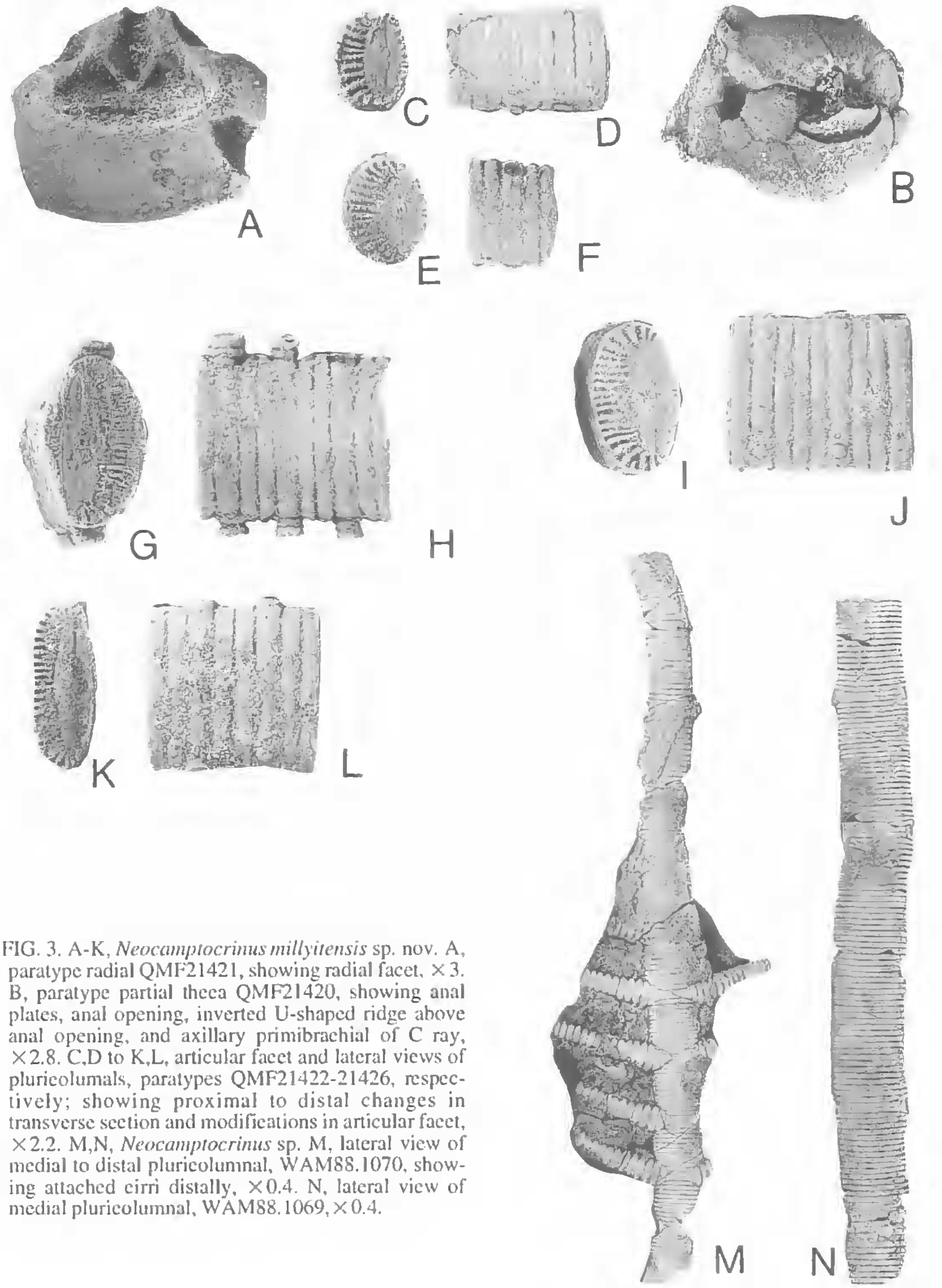


FIG. 3. A-K, *Neocamptocrinus millyitensis* sp. nov. A, paratype radial QMF21421, showing radial facet, ×3. B, paratype partial theca QMF21420, showing anal plates, anal opening, inverted U-shaped ridge above anal opening, and axillary primibrachial of C ray, ×2.8. C,D to K,L, articular facet and lateral views of pluricolumals, paratypes QMF21422-21426, respectively; showing proximal to distal changes in transverse section and modifications in articular facet, ×2.2. M,N, *Neocamptocrinus* sp. M, lateral view of medial to distal pluricolumnal, WAM88.1070, showing attached cirri distally, ×0.4. N, lateral view of medial pluricolumnal, WAM88.1069, ×0.4.

21426 from QML772,Millyit Range, Canning Basin from the Cherrabun Member, Hardman Formation.

DESCRIPTION
See Webster, 1990:57.

REMARKS
Webster (1990) left material available at that time in open nomenclature because its precise locality and horizon were unknown. We have now collected further material from a well-defined locality and horizon, which may well be the type locality.

The partial theca shows 3 anal plates, with a large primanal in the radial circlet, a small anal opening above the central anal plate and an inverted V-shaped ridge on the overlying oral. Both orals bear a coarse central node. Radial facet has a transverse ridge with a parallel shallow outer ligament pit, two shallow muscle fields and a T-shaped ambulacral track aborally.

Pluricolumnals are mostly short segments but show the change in sectional shape from nearly circular proximally to distally elliptical. The articular facet of the proximal columnals has long coarse culmina on the upper side of the columnal and very short culmina on the under side. Culmina become coarser laterally on the facet. The areola is higher on the upper side with faint traces of culmina across the surface. On the underside, the areola is smooth and half the width of that on the upper side. Axial canal is small and round.

Neocamptocrinus sp.
(Fig. 3M,N)

MATERIAL
Pluricolumnals WAM88 1069-88 1070 from north bank, Minilya River in the fourth massive sandstone of the Wandagee Formation, Coolkilya Pool area, Wandagee Station. Collected K.J. McNamara.

REMARKS
These are the longest articulated pluricolumnals of *Neocamptocrinus* known from Western Australia. They are 28cm and 28.5cm long with columnals 30mm wide, 9mm thick and 2.2mm high. In a proximal direction noditaxes consisted of 22, 23, 24, and 26 columnals each on WAM88.1069. Cirri are initiated at the junction between two columnals and may grow to extend over the height of four columnals; the axial canal is also shared by the two columnals. Columnal growth after initial growth of the cirrus extends beyond the distal edge of the proximal cirral to partly cover the proximal end of the second cirral. Cirri are round in section. Crenularium 1.8mm wide, slightly less than half cirral radius (4.1mm); culmina fine. Areola planar. Axial canal small and round. Cirri taper distally with semipointed ends. These large columnals lack the more rounded proximal and distal sections of the stem. They show that considerable lengths of the stem acted as a runner with the cirri extended out and down into the substrate. It is unknown if the flexures in the two stem sections reflect flexibility around substrate irregularities or diagenetic distortion.

Stomiocrinus Wanner, 1937

TYPE SPECIES
Stomiocrinus subglobosus Wanner, 1937 from the Permian of Timor; by original designation.

Stomiocrinus merlinleighensis sp. nov.
(Fig. 2D-F)

ETYMOLOGY
For the Merlinleigh Subbasin, Carnarvon Basin.

MATERIAL
Holotype CPC30669, paratypes CPC30670-30676 from micaceous limestone in the top of the Bulgadoo Shale, at type locality, near Donnelly's Well.

DIAGNOSIS
Orals elongate, steeply upflared, visible in lateral view.

DESCRIPTION
Crown small, cylindrical. Cup bullet-shaped, widest at radial summit, fine shagreen ornamentation. BB 2, equidimensional, forming lower 1/3 of cup, upflared steeply; interbasal suture in plane of symmetry. RR 5, longer than wide, outflaring gently longitudinally, moderately convex transversely, straight to slightly convex longitudinally. Radial facets angustary, approximately 1/3 greatest radial width, subhorizontal. Brachials rectilinear, longer than wide, strongly convex transversely, straight longitudinally; IBr_2 or $_3$ axillary; one additional branching in some rays, all branchings isotomous. No pinnules. Anal in radial circlet, slightly narrower than radials. OO 5, elongate, steeply upflared, raised medial section flush to slightly inset to proximal brachials, mutual lateral edges underlay proximal brachials and form base of ambulacral groove from the base of the arms to the mouth. Posterior oral largest.

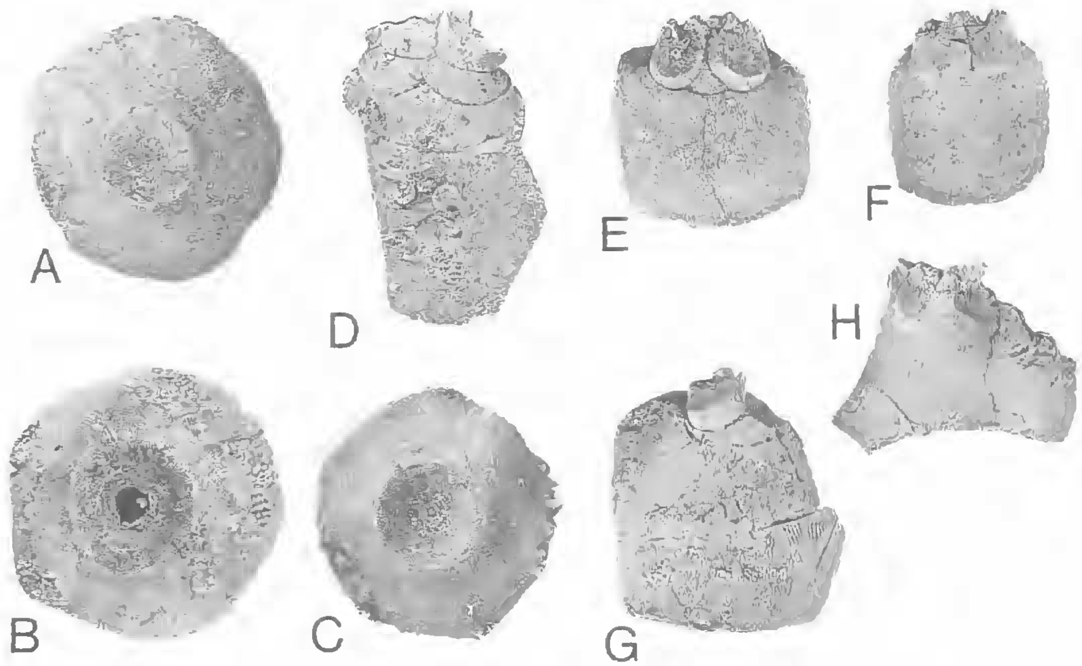


FIG. 4. *Neoplatycrinus callytharraensis* sp. nov. all from QML757, ×1. A-C, basal circlets QMF21594, 21593, and 21592, respectively. D–H, radials with primibrachs and in some cases secundibrachs attached, QMF21595, 21599, 21597, 21598, and 21596, respectively.

MEASUREMENTS (mm)

	Holotype	Paratype
Crown length	3.6 (incomplete)	3.3
Crown width	1.5	1.2
Cup length	1.6	1.2
Cup width	1.3	1.1
Basal circlet diameter	0.7	0.7
Basal circlet length	0.6	0.6
Radial length	1.0	0.8
Radial width	0.8	0.7

REMARKS

Stomiocrinus is reported from the Permian of Timor, Russia (Broadhead, 1981) and Western Australia (Webster, 1990). Broadhead (1981) assigned *Stomiocrinus* to the Camptocrininae based on Yakovlev's (in Yakovlev & Ivanov, 1956) combination of disassociated thecae and bilaterally symmetrical columnals. The crowns of *S. merlinleighensis* occur on three small blocks associated with *Jimbacrinus donnellyensis* and *Calceolispongia acuminata*. None of the crowns of *S. merlinleighensis* has the stem attached whereas the crowns of *J. donnellyensis* have the proximal stem attached. It is unknown if the proximal stem of *C. acuminata* is attached.

In the matrix there are numerous thin round pluricolumnals which contain columnals of 4mm diameter and 7mm length that might have been the stem of *S. merlinleighensis*. They differ from the short cirral segments (7mm diameter, 2mm long) which are articulated with the attached stems on *J. donnellyensis*. There are no bilaterally symmetrical columnals in the matrix. This leaves the subfamily affinity of *Stomiocrinus* in doubt until articulated thecae and columnals are found.

Superfamily PLATYCRINITOIDEA Austin & Austin, 1842

Family PLATYCRINITIDAE Austin & Austin, 1842

Neoplatycrinus Wanner, 1916

TYPE SPECIES

Neoplatycrinus dilatatus Wanner, 1916, from the Permian of Timor; by original designation.

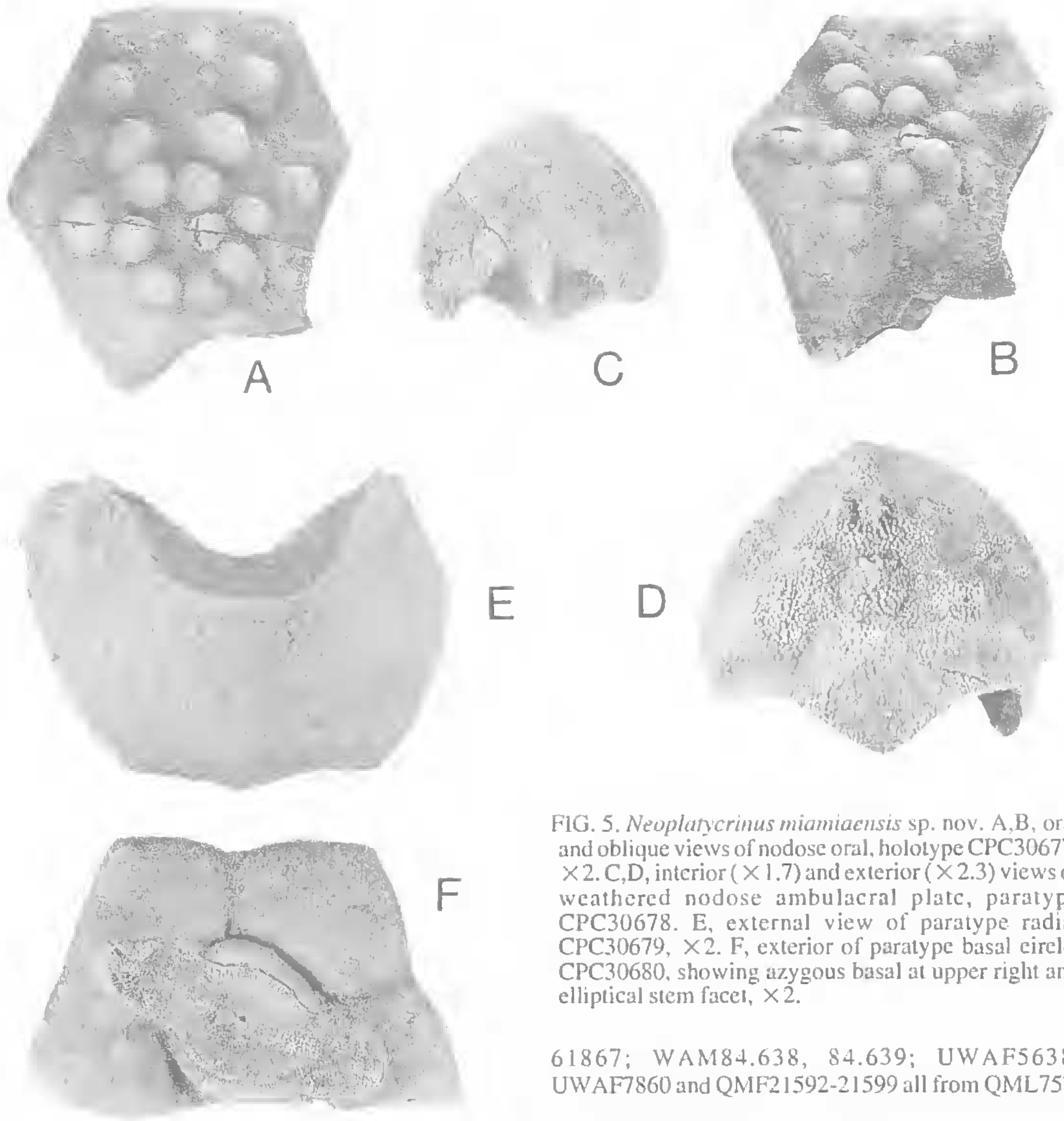


FIG. 5. *Neoplatycrinus miamiaensis* sp. nov. A,B, oral and oblique views of nodose oral, holotype CPC30677, ×2. C,D, interior (×1.7) and exterior (×2.3) views of weathered nodose ambulacral plate, paratype CPC30678. E, external view of paratype radial CPC30679, ×2. F, exterior of paratype basal circlet CPC30680, showing azygous basal at upper right and elliptical stem facet, ×2.

Neoplatycrinus callytharraensis sp. nov. (Fig.4)

Neoplatycrinus aff. *N. somoholensis* Wanner, 1916; Webster, 1987:100, figs 4A-O.
Pleurocrinus? sp. Webster, 1987:101, fig. 4P,Q.

ETYMOLOGY
For Callytharra Springs.

MATERIAL
Holotype UMMP61862. Paratypes UMMP61863-61867; WAM84.638, 84.639; UWAF5638, UWAF7860 and QMF21592-21599 all from QML757.

DIAGNOSIS
Oral and ambulacral plates with large node or coarse ridges.

DESCRIPTION
As given by Webster, 1987, p. 100-101.

REMARKS
This species is based on disarticulated oral and ambulacral plates bearing one very large node and secondary smaller nodes or very coarse discontinuous ridges. Basal and radial plates assigned lack these coarse nodes as is the case in *N.*

miamiaensis, described below. We found the ornamented orals and ambulacral plates disassociated in proximity to the unornamented basal circlets and radials.

Webster, 1987, referred the Callytharra Formation specimens to *N.* aff. *N. somoholensis*, a species based on internal molds (Wanner, 1916, 1924a). The ambulacral plates of *N. somoholensis* are divided distally by a deep V-shaped separation (Wanner, 1924a, pl. 3, fig. 2). Division on the ambulacral plates of *N. callytharrensis* is not as deep (Webster, 1987, fig. 4A). The upper distal part of oral plates of *N. somoholensis* would overhang the proximal vertical section whereas they do not on *N. callytharraensis*. All other described species of *Neoplatycrinus* lack ornamentation on the oral and ambulacral plates.

Neoplatycrinus miamiaensis sp. nov.
(Fig. 5)

ETYMOLOGY

For Mia Mia Station.

MATERIAL

Holotype CPC30677, paratypes CPC30678-30681 all from the lowermost fossiliferous horizon in the Artinskian Coyrie Formation, east of Mia Mia Homestead, 23°21'S, 114°34'E, northern Carnarvon Basin. Other material CPC30711-307153, a columnal, 2 radials and 2 tegmen plates from the lower part of the Noonkanbah Formation at the type section (BMR loc. KNF73), Canning Basin.

DIAGNOSIS

Basal circlet subhorizontal; orals and ambulacrals bearing coarse nodes in radiating to irregular patterns.

DESCRIPTION

Basal circlet large, estimated 32mm diameter, subhorizontal; bears elliptical stem facet, 2.3mm long, 9.3mm wide. BB 3, 2 large, 1 small (16mm long, 15.5mm wide) surface coarsely granulate, with coarse node (2.8mm diameter) on one plate. RR 5, wider (28.4mm) than long (20.7mm), convex longitudinally and transversely, surface with coarse granules, no nodes. Radial facet wide, 2/3 plate width, narrow, crescent shaped. OO 5, large, estimated 35mm long, 28.2mm wide, polygonal, proximally vertical, distally subhorizontal or upflared, with 8 to 18 coarse nodes (4.4mm diameter, 2.8mm high) in radiating or irregular pattern and coarse granular ornament. Proximal ambulacral quadrangular, 18.9mm long, 19.3mm wide, sharply pointed proximally and distally, side vertical, exterior with up to 9 coarse nodes and coarse granular ornamentation.

REMARKS

The description is based on disarticulated ossicles from one horizon in the Coyrie Formation. The theca is estimated to have been up to 75mm wide and 45mm high, with a low bowl shape having a flat base, low out-flared radials, and a broad flat to upflared tegmen. Interpretation of the theca is based on: 1, a flat wide basal circlet (Fig. 5F); 2, radials attached to the vertical facets on the basal circlet such that the proximal end of the radial was horizontal, expanding the low bowl laterally; 3, radials are convex longitudinally resulting in the distal parts of the radial being essentially vertical; the radial facet would have sloped down and out at an estimated 80°; and 4, the proximal end of the orals was probably nearly vertical and the distal part subhorizontal to upflared perhaps as much as 40°. Mutual facets on the radials and orals are not well preserved precluding firm estimate of reconstruction.

Secundibrachials associated with the thecal plates bear the same coarse nodes and granulate ornamentation. They are U-shaped with two deep V-shaped ambulacral grooves, one large and one smaller and lateral. Most plates show growth bands on the aboral side. Solution weathering has modified the surfaces of most plates, removing or obliterating the granular ornament is common, and in extreme examples nodes are reduced to small stellate elevations. Diagenetic distortion and fracturing followed by calcite cementation sealing the fractures is present on some plates.

Numerous internodals and nodals of the "twist" nodal columnals were found in association with the thecal plates. They are assigned to the species because all other crinoids in the fauna are non platycrinitids. No difference could be discerned between these columnals and ones found in the Callytharra Formation. This suggests that mosaic evolution was occurring in the theca while the columns were stable.

Neoplatycrinus is restricted to the Permian of Timor (Lane in Moore & Teichert, 1978) and Western Australia (Webster, 1987). The genus is recognized by the large oral plates. *N. miamiaensis* is distinguished from *N. callytharraensis* by its oral and ambulacral plate ornamentation. It differs from *N. somoholensis* by having a flat base instead of being upflared at 30° to 40°. Evolution of *N. miamiaensis* from *N. callytharraensis* occurred by modification of oral and ambulacral ornament.

The original field label on specimens of *N.*

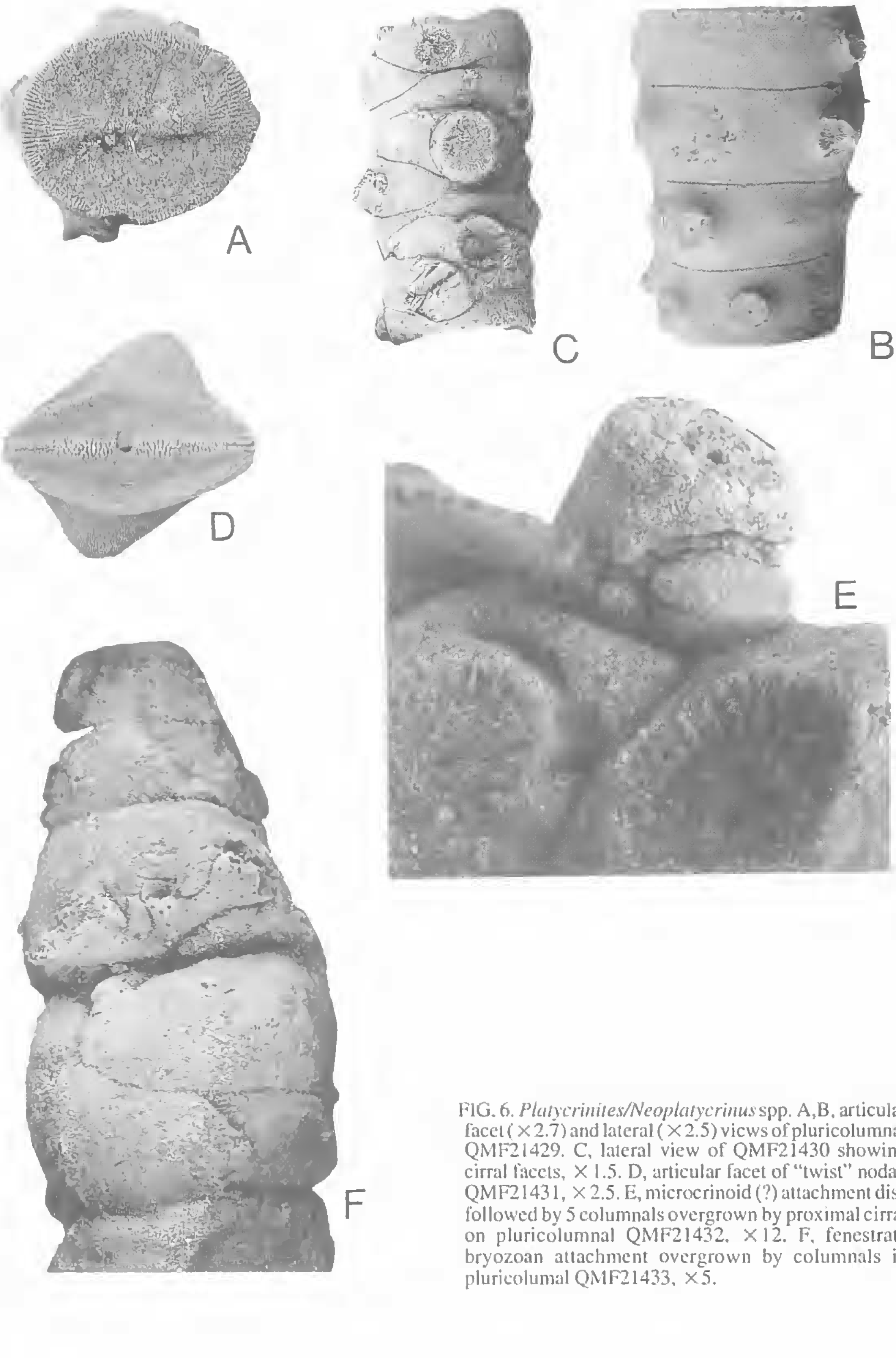


FIG. 6. *Platycrinites/Neoplatycrinus* spp. A,B, articular facet (×2.7) and lateral (×2.5) views of pluricolumnal QMF21429. C, lateral view of QMF21430 showing cirral facets, ×1.5. D, articular facet of "twist" nodal, QMF21431, ×2.5. E, microcrinoid (?) attachment disc followed by 5 columnals overgrown by proximal cirral on pluricolumnal QMF21432, ×12. F, fenestrate bryozoan attachment overgrown by columnals in pluricolumal QMF21433, ×5.

miamiaensis gave the stratigraphic unit as the Bulgadoo Shale. However the latitudinal coordinates place the locality in the Coyric Formation as mapped on the Winning Pool-Minilya 1:250,000 Geological Sheet SF50-13, 1984.

The columnal, radials and tegmen plates from the Canning Basin bear the same ornamentation on the oral and brachial as described above.

Platycrinites/Neoplatycrinus spp.
(Fig. 6)

MATERIAL

Figured material QMF21429,21431 from QML760, QMF21430, 21432, 21433 from QML757 and other material 181 internodals, 102 nodals and 39 pluricolumnals QMF21578 (203) from QML757, QMF21579 (26) from QML758, QMF21580 (14) from QML759, QMF21581 (13) from QML760, QMF21582 (9) from QML761, QMF21583 (19) from QML758-761, QMF21584 (18) from QML769 and QMF21585 (6) from QML770.

DESCRIPTION

Internodals elliptical, opposing fulcral ridges parallel; nodals rectangular to subquadrate, opposing fulcral ridges at 15-80° with most 67° or 80°. All columnals wider than high, elliptical axial canal, very fine shagreen ornamentation. Noditaxis variable, 1-5 internodals. Articulum divided in half by prominent fulcral ridge. Fulcral ridge depressed below articular rim adjacent to axial canal, bears transverse vermiform to short medium coarse ridges proximally, 3 to 7 medium coarse slightly radiating culmina distally. Crenularium narrow; culmina short, medium coarse, lengthening near fulcal ridge, producing a fan shaped pattern, unbranched. Areola divided by fulcral ridges, each half crescent in outline, smooth, sloping into shallow trough paralleling fulcral ridge, deepest abaxial of axial canal. Axial canal small, elongate parallel to fulcral ridge. Latus gently to moderately convex on lateral sides, moderately convex to vertical to gently concave on ends of internodals, rarely bears small nodes. May bear cirri in distal most parts of stem.

Cirri round transversely; articulum round. Crenularium 1/3 radius; culmina coarse, cog-like, may branch isotomously once. Areola smooth, flat. Axial canal round.

REMARKS

The elliptical columnals vary from elongate (18.6 x 9.4mm) to subcircular (21.8 x 19.5mm) in adults. The more subcircular specimens are mostly cirral bearing and judged to be more distal columnals, whereas the more elongate elliptical forms lack cirri and are considered to be more proximal. Thickness of individual nodals and internodals is uniform except in the cirral bearing distal stem parts where they show pinching and swelling in lateral view.

Cirral facets occur on nodals or internodals and slant distally 5-10°. They are most commonly developed on one or both ends of the long axis but also occur along the short axis of the facet. There are up to 4 cirri per columnal, with one the most common. First cirrus is wedge shaped with distal facet sloping distally thereby increasing the distal slope of the cirrus. Cirri short, tapering distally.

Most specimens are weathered with loss of surface articulum and axial canal details and enhancement of growth bands. Up to 11-14 growth bands weathered as ridges and grooves. Similar growth bands on large cup plates of *Neoplatycrinus* aff. *N. somoholeusis*, *Platycrinites wrighti* and *Pleurocrinus*? sp. were illustrated by Webster (1987). These columnals probably belong to those species and are therefore left in open nomenclature.

Organisms attached to the living column of *Platycriuites/Neoplatycriuus* spp. include bryozoans (Fig.6F) and other crinoids (Fig.6E) as both are found overgrown by columnals or cirri. *Phosphannulus* infestations are rare on *Platycrinites/Neoplatycrinus* spp. Columnals, as postmortem detrital grains were used as attachment sites by various sessile organisms but most commonly bryozoans. Diagenetic compaction distorts the areola of numerous specimens.

Subclass INADUNATA Wachsmuth & Springer, 1885
Order DISPARIDA Moore & Laudon, 1943
Superfamily ALLAGECRINOIDEA Carpenter &Etheridge, 1881
Family ALLAGECRINIDAE Carpenter & Etheridge, 1881

Wrightocrinus Moore, 1940

TYPE SPECIES

Allagecrinus jakovlevi Wanner, 1929 from the Permian of Timor; by original designation.

Wrightocrinus wooramelensis sp. nov.
(Fig. 7A,B, I-K)

ETYMOLOGY

For the Wooramel River.

MATERIAL

Holotype QMF21438 from QML757, paratypes

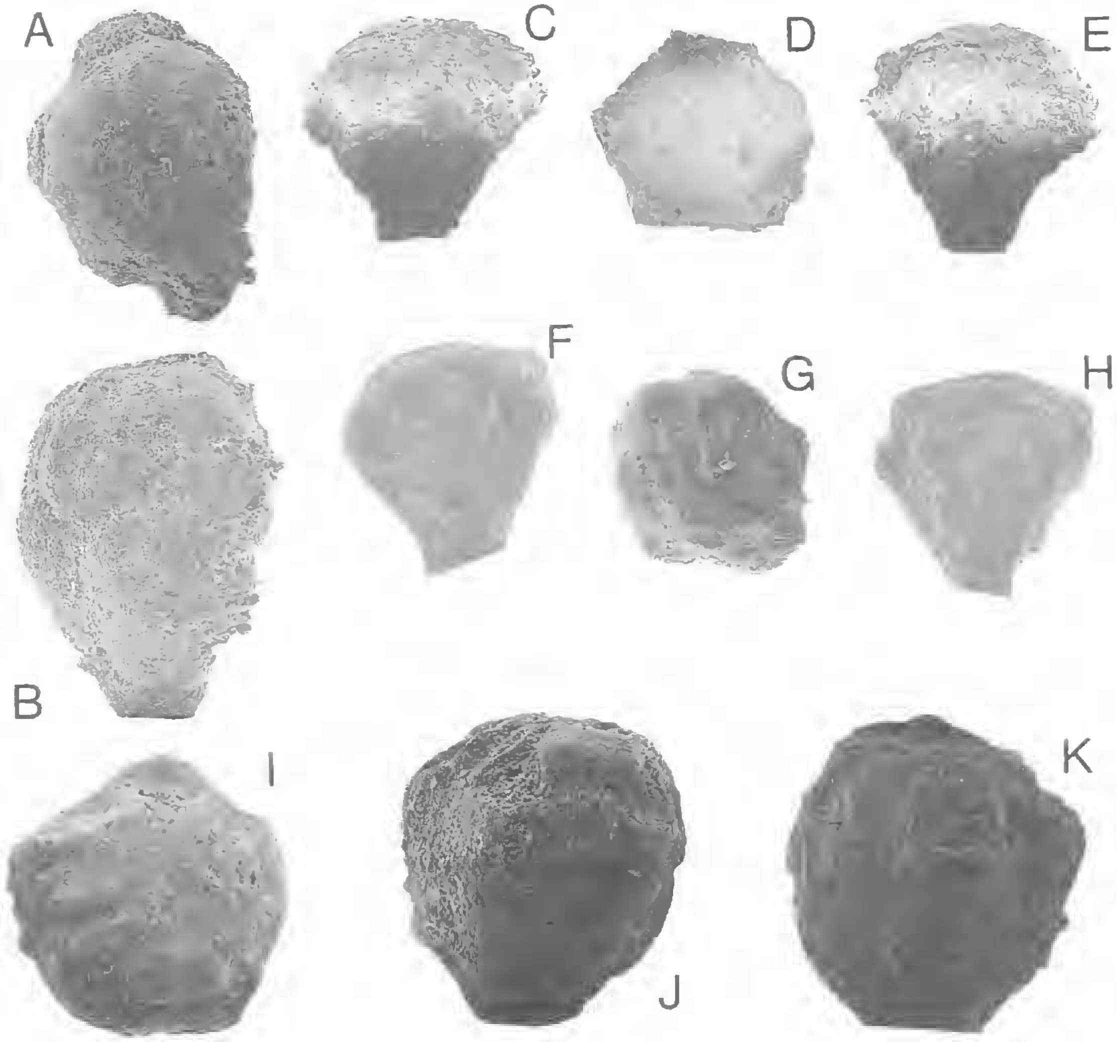


FIG. 7. A,B, I-K, *Wrightocrinus wooramelensis* sp. nov. oral and C ray views of partly crushed paratype QMF21439, A ×30; B ×40. I-K, oral, posterior and A ray views, of holotype QMF21438, ×30. C-H, *Litocrinus pansus* sp. nov. C-E, AB interay, oral and D ray views of holotype QMF21448, ×40. F-H, A ray, oral and posterior views of paratype QMF21449 ×40.

QMF21439 (QML760), CPC30692 (QML757-761) and three crushed thecae QMF21554 (QML759), QMF21555(QML761), all from west of Callytharra Springs.

Diagnosis

Radials protuberent; radial facets narrow; basals short; orals with an elongate central depression.

Description

Theca 1.1mm high, 1.0mm wide, globose, convex walls in lateral view, rounded pentagonal outline in oral view, walls smooth. BB 2, suture slightly rotated off A-CD plane, low, proximally horizontal, bearing round articular facet for stem, distally upturned, flaring outward, forming lower 1/5 of cup. RR 5, 3/4 as wide as long, widest at midlength, outflared proximally, incurved distally, moderately convex longitudinally, transversely gently convex proximally, strongly convex distally, with one facet each; radial facets peneplenary, sloping inward, pit-like. Slight anal notch on mutual shoulders of C and D radials. OO 5, elliptical, slightly longer than wide, central linear depression bordered by rounded low ridge,

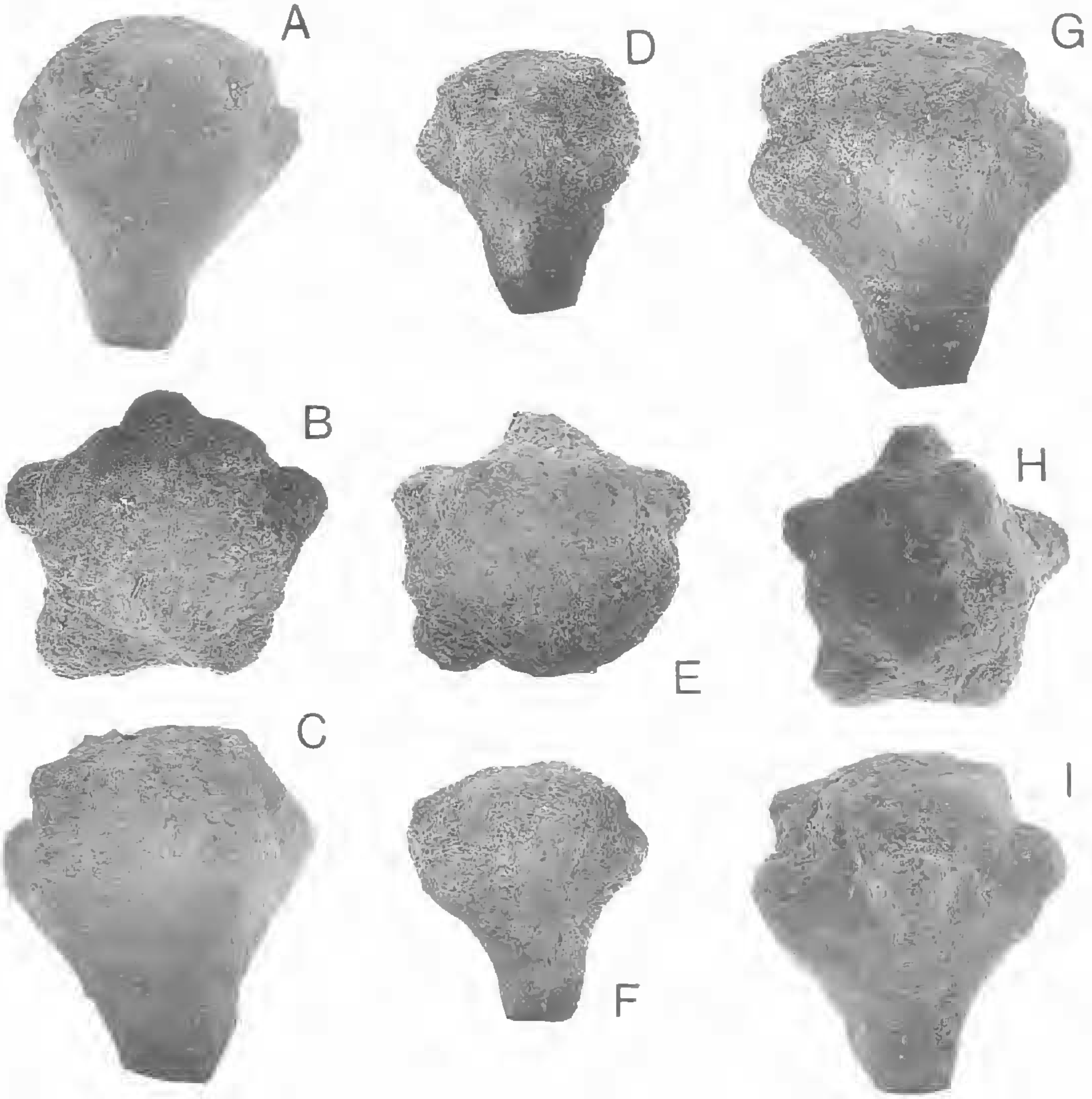


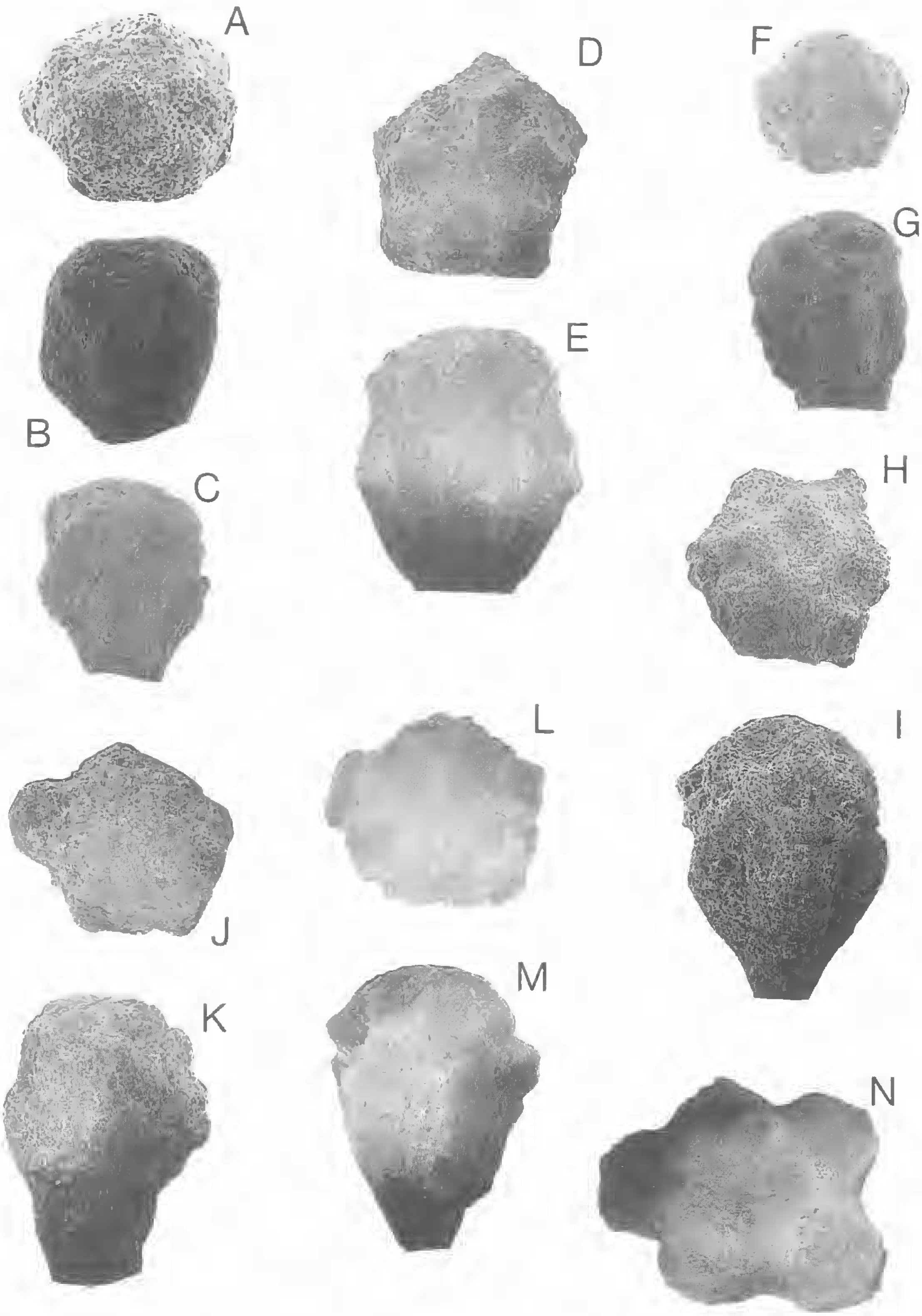
FIG. 8. *Litocrinus protuberans* sp. nov. A-C, BC interray, oral and posterior views of paratype QMF21441, ×40. D-F, A ray, oral and posterior views of paratype QMF21442, D ×40; E ×50; F ×40. G-I, A ray, oral and E ray views of holotype QMF21440, ×40.

form flat-topped elevated circlet slightly inset from radial summit. Posterior basal largest, as wide as long, separating BC and DE orals.

REMARKS

The holotype has a small calcite deposit on the EA oral extending onto the mutual shoulders of the E and A radials. At a cursory glance this falsely appears to be the posterior oral. The posterior oral is recognised by the suture with the other four orals and the small anal notch below it. All specimens of *W. wooramelensis* may be immature, lacking the development of additional arms in the A, C and D rays.

The globose appearance of *W. wooramelensis* is similar to immature specimens of *W. jakovlevi* (Wanner, 1929) but distinguished from it by having more protuberant radials, narrower radial facets, shorter basals and orals bearing an elongate central depression. Webster & Jell, in press, discussed the reasons, essentially that one is a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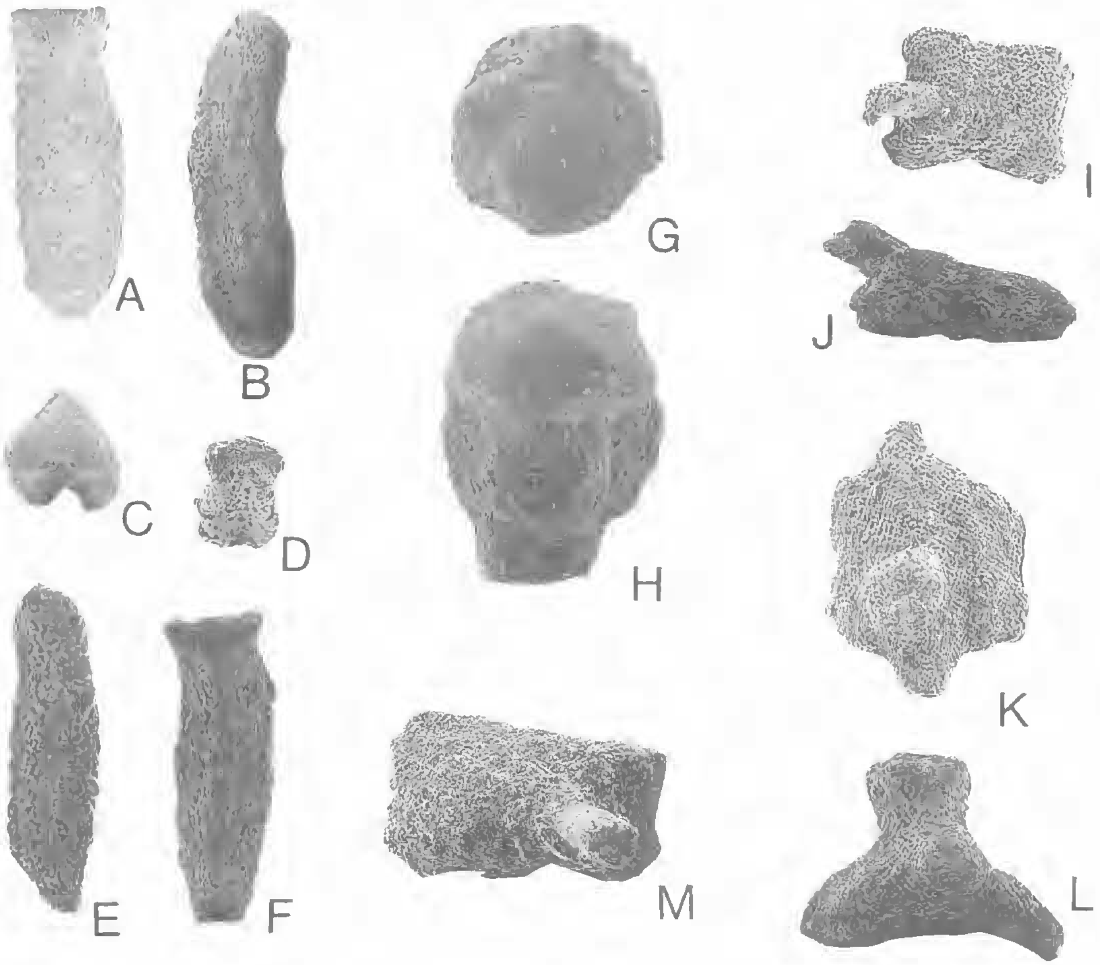


FIG. 10. A-H, *Synbathocrinus constrictus* (Wanner, 1916), initial brachials. A-C, aboral, lateral and brachial facet views, QMF21478, ×25. D-F, brachial facet, lateral and aboral views of QMF21479. A ×25; B,C ×30 . G,H, oral and C ray views of abnormal specimen with only 4 rays and 4 oral plates, QMF21462, ×30. I-M, Microcrinoid holdfasts gen. et sp. indet. I,J, oral and lateral views of rectangular shaped base, QMF21477. I ×25; J ×30. K,L, oral and lateral views of hexagonal base QMF21475. K ×25; L ×30. M, oral view of rectangular base QMF21476, ×30.

FIG. 9. *Synbathocrinus constrictus* (Wanner, 1916). A-C, oral, A ray and E ray views of QMF21461, A ×50; B,C ×40. D,E, oral and B ray views of QMF21464, ×30. F,G, oral and C ray views of abnormal specimen, A and B rays semifused, QMF21467, ×25. H,I, oral and D ray views of pre arm stage QMF21460, ×50. J,K, oral and B ray views of one armed stage, QMF21465, ×30. L,M, oral and A ray views of 2- armed stage, QMF21466, ×20. N, oral view of 4-armed stage, QMF21463, ×20.

juvenile of the other, for placing *Allagecrinus quinquebrachiatus* Wanner, 1929 in synonomy with *W. jakovlevi*.

Litocrinus Lane & Sevastopulo, 1982

TYPE SPECIES

Kallimorphocrinus punctatus Lane & Sevastopulo, 1981, from the Lower Carboniferous of Tennessee; by original designation.

Litocrinus pansus sp. nov.
(Fig. 7C-H)

ETYMOLOGY

Latin *pansus*, spread out, extend.

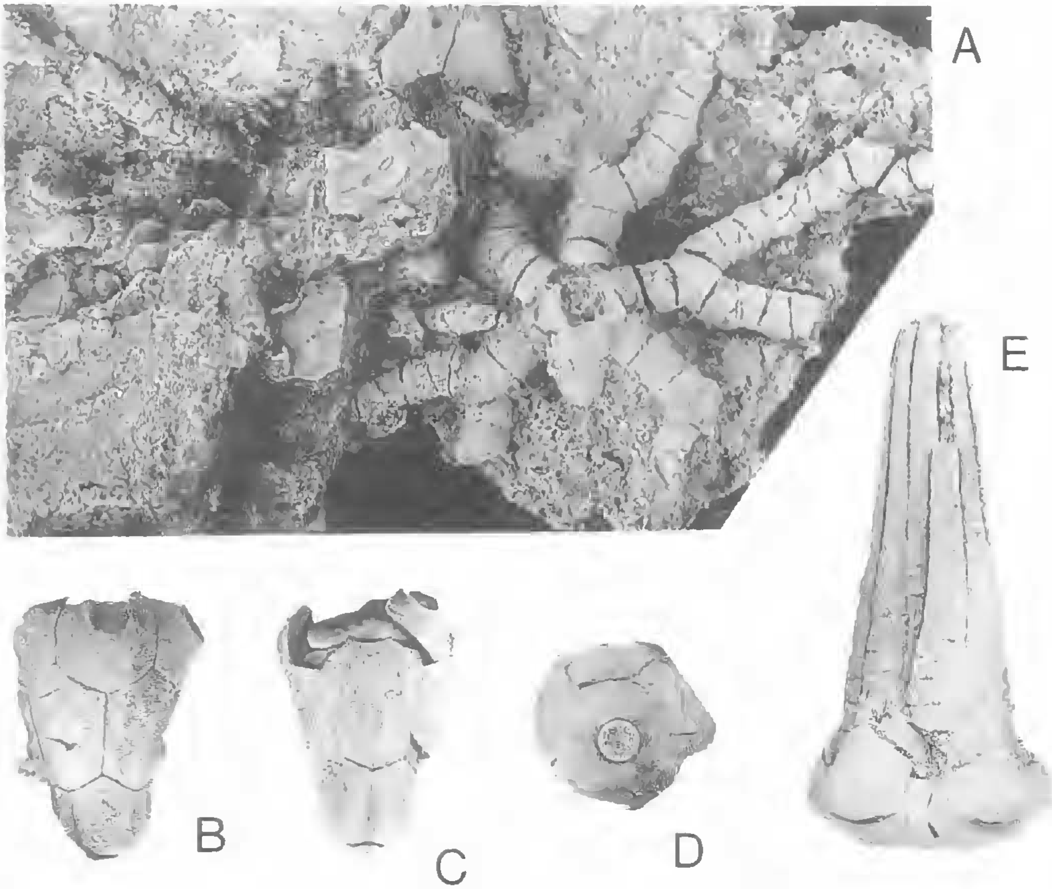


FIG. 11. A, *Spheniscocrinus australis* sp. nov., basal view of holotype, showing base of anal tube in 6 o'clock position on cup, CPC30682, ×3. B-D, *Occiducrinus australis* Webster, 1990, A ray, posterior and basal views of QMF21427, ×1. E, *Tapinocrinus spinosus* (Wanner, 1924a), posterior view showing distal tips of arms, QMF21427, ×1.6.

MATERIAL

Holotype QMF21448 from QML760, paratype QMF21447, 21449 from QML757, QMF21446 from QML759, and other material QMF21556 (1) from QML757, QMF21557 (3) from QML759, QMF21558 (1) from QML760 and QMF21559 from QML761.

DIAGNOSIS

Theca expanded markedly above narrow basal circlet; oral circlet dome-shaped.

DESCRIPTION

Theca small, equidimensional, 0.4-0.6mm, pyriform, walls concave, expanding rapidly above basal circlet, unornamented. BB 5 or fused, small, forming lower 40% of cup, gently outflared. RR 5, longer than wide, moderately convex transversely, concave longitudinally with straight to convex distal ends, may be weakly protruding distally. OO 5, rounded proximal edge in oral view, proximally steeply upflared, distally subhorizontal, may bear weakly elevated protrusion at upflaring to subhorizontal flexures, forming domed arch with diameter less than thecal max. just below radial summit; posterior oral larger, separating BC and DE orals.

REMARKS

L. pansus is variable in development of protrusions on orals and may develop a weak node distally on the radials. Without careful observation *L. pansus* could be considered a juvenile or variant of *L. protuberans*. However, the species differs from *L. protuberans* by the greater lateral expansion, lack of strongly protruded radials and more rounded dome shape of the oral circlet. It is the smallest form in the Callytharra fauna.

Litocrinus protuberans sp. nov.
(Fig. 8)

ETYMOLOGY
Latin *protuberosus*, protuberant; for the radials.

MATERIAL
Holotype QMF21440 from QML759, paratypes QMF21441 from QML758, QMF21442, 21443 from QML759, QMF21444 from QML760, QMF21445 from QML757, and other material QMF21560 (8) from QML757, QMF21561 (3) from QML758, QMF21562 (15) from QML759, QMF21563 (19) from QML760, QMF21564 (3) from QML761, QMF21565 (5) from QML757-761.

DIAGNOSIS
Radials with evenly rounded large protuberances.

DESCRIPTION
Thecae small, largest specimen 1.1mm high, 0.9mm wide, turbinate to pyriform, walls expand rapidly from base of radials to large protuberances in distal part of radials, capped by oral circlet, strongly pentalobate in oral view, unornamented. Basals fused, bear circular stem facet proximally, gently outflaring distally, forming lower 1/3 of cup. RR 5, slightly longer than wide, expanding rapidly upward, longitudinally concave proximally to strongly convex distally, transversely gently convex proximally strongly convex distally; large smooth growth protuberance on distal part of radial. No anal notch on plates. OO 5, slightly longer than wide to subequal to wider than long, slightly irregular outer surface, vertical to slightly inflared proximally, subhorizontal to gently arched distally. Posterior oral largest, separating BC and DE orals, bearing small hydropore or madreporite. Oral circlet slightly inset on radial summits.

REMARKS
Growth sequence from 0.4-1.1mm present in the 67 specimens studied. Initially the theca is equidimensional and the radial protuberances are recognisable but not domineering as the cup wall flares moderately and evenly from the stem facet to the radial protuberances. As growth continues radials elongate and the protuberance expands to become the most noticeable morphologic feature of the theca. The base of the cup is relatively narrow and most of the wall flaring is with the radials.

No other species of *Litocrinus* has as strongly protruded distal parts of the radials as *L. protuberans*. There is a large node in the centre of each radial on the Late Permian *L. palermoensis* (Strimple & Sevastopulo, 1982) from Sicily that is a later evolved form.

Family CATILLOCRINIDAE Wachsmuth and Springer, 1886.

Notiocatillocrinus Willink, 1978

TYPE SPECIES
Notiocatillocrinus oakiensis Willink, 1978, from the Lower Permian of NSW; by original designation.

Notiocatillocrinus callytharraensis
Webster, 1987 (Fig. 14E)

Notiocatillocrinus callytharraensis Webster, 1987: 108, figs 7, 8.

MATERIAL
One weathered crown NMVP127202 from Fossil Hill, Bidgermia Station, GR351884 on Glenburgh 1:250,000 Geological Sheet SG 50. Collected by G.A. Thomas.

REMARKS
This is the largest specimen known. It is twice the length of the holotype and displays an excellent cross-section of the cup and tegmen.

Easily recognisable radials, showing the multiple arm facets, cups and the horseshoe-shaped tegmen plates of *N. callytharraensis* were found at every locality visited. Often they were embedded in the grainstones and not retrieveable without excessive labour. These plates make excellent index fossils in the Callytharra Formation throughout the Carnarvon Basin.

Superfamily BELEMNOCRINOIDEA Miller, 1883
Family SYNBATHOCRINIDAE Miller, 1889

Synbathocrinus Phillips, 1836

TYPE SPECIES
Synbathocrinus conicus Phillips, 1836 from the Lower Carboniferous of England; by monotypy.

Synbathocrinus constrictus (Wanner, 1916)
(Figs 9, 10A-H)

MATERIAL
Figured specimens QMF21460, 21461, 21463, 21465,

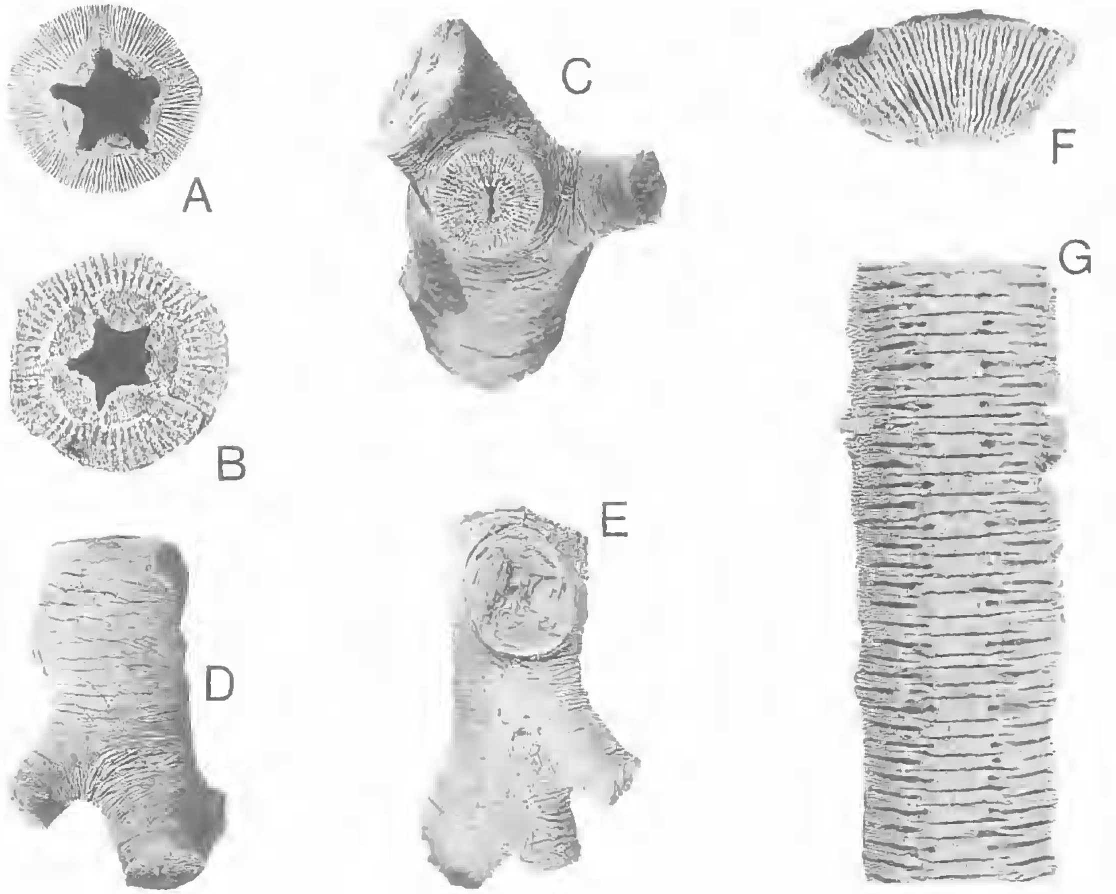


FIG. 12. Barycrinid? gen. indet. A, articular facet of pentameric columnal QMF21434, × 1.4. B, articular facet of pentameric pleuricolumnal QMF21435, × 1.7. C-E, root holdfast with branchlets or cirri, QMF21436, × 1.4. C, enlargement of articular facet of non-pentameric rootlet cirri. D,E, lateral views of holdfast in possible growth position. F,G, articular facet and inner lateral views of weathered pleuripentamere QMF21437, × 1.8.

21466, 21478, 21479 from QML759, QMF21462 from QML758, QMF21464, 21467 from QMI757 and other material QMF21571 (23) from QML757, QMF21572 (3) from QML758, QMF21573 (37) from QML759, QMF21574 (7) from QML760, QMF21575 (1) from QML761, and QMF21576 (6) from QML758-761.

REMARKS

Articulated thecae of juvenile and adult specimens of *Synbathocrinus constrictus* are moderately abundant throughout the interbedded arenaceous shales and limestones of the lower fossiliferous part of the Callytharra Formation at Callytharra Springs. Juvenile spec-imens are 0.4-2.5mm high and include growth stages from the armless embryonic through 5-armed forms.

Early growth stages are dominated by inflated orals and protuberant radials with a low narrow basal circlet. Radials and orals increase in length rapidly, are approximately equal in height and are the most obvious plates in the theca during early development. Radials show an early development of the medial longitudinal ridge, whereas orals are initially inflated then gradually develop a shallow central depression. The CD oral is largest, adjoining all other orals, separating the BC and DE orals, and bearing a small central protuberance, the hydropore or madreporite. At 1.3mm thecal height radials are approximately twice the height of the oral circlet and the first radial facet develops on the E radial. Growth continues in a linear increase greater than transverse until approximately 2.5mm height when lateral expansion is rapid. Arms develop in sequence in the C, B, D and A

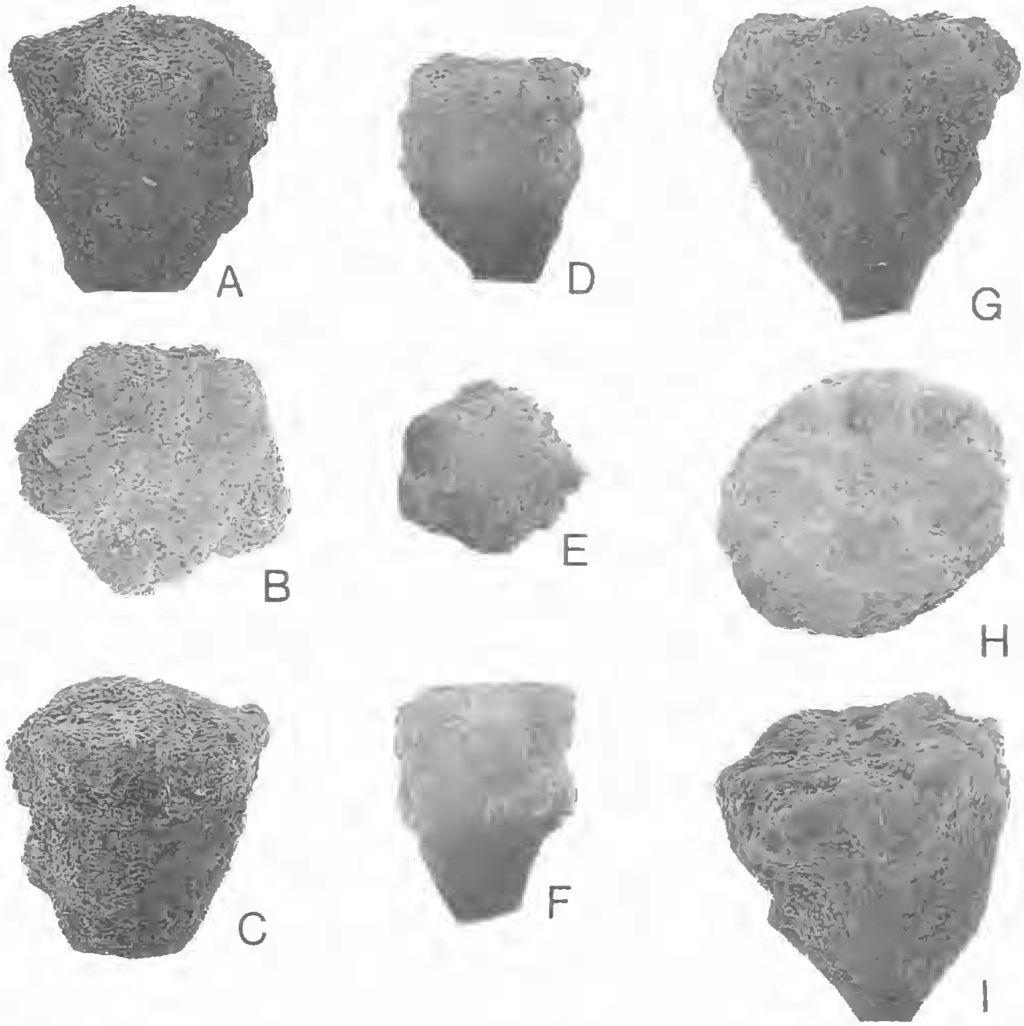


FIG. 13. *Lampadosocrinus variabilis* sp. nov. A-C, A ray, oral and C ray views of paratype QMF21451, ×40. D-F, A ray, oral and DE interray views of paratype QMF21452, ×40. G-I, E ray, oral and C ray views of holotype QMF21450, ×40.

rays. Only single specimens of most of the different arm stages are known. It is not known if the same sequential arm development is regularly followed. Orals are retained with the development of the fifth arm and the anal plate is not developed although a faint depression may occur in the radial circlet at the mutual shoulders of the C and D radials below the posterior oral. Macro specimens lack the oral circlet and were illustrated by Webster (1987).

Two abnormal specimens lack part or all of the fifth ray. One (Fig. 8G,H) has 4 radials and 4 orals. Except by careful examination it appears to be a normal 5 rayed theca. The other (Fig. 7F,G) has a partial fusing of the A and B radials and orals are distorted.

Small brachials up to 2.5mm long in the disarticulated washings are judged to be the beginning growth stages of arms of *S. constrictus* on the basis of the articular facet and the medial longitudinal ridge. Two of these brachials are illustrated to show the variation in longitudinal curvature, shape, ambulacral groove and distal tips.

These thecae are assigned to *S. constrictus* because they show the prominent radial ridge. Webster (1987) noted the gradation between *S. constrictus* and *S. campanulatus* so some of these may be immature specimens of *S. campanulatus* but that form is not recognised until its adult stage.

Family UNCERTAIN

Microcrinoid holdfasts gen. et sp. indet.
(Fig. 10I-M)

MATERIAL
QMF21475-21477 from QML759 and QMF21577 from QML757-761 west of Callytharra Springs.

DESCRIPTION
Base hexagonal, rectangular or irregularly polygonal; sides scalloped to irregular; thickened centrally or towards one end extending as base of round columnal. Base concave.

REMARKS
Holdfasts 1.0-2.0mm long, 0.5-1.5mm wide and 0.6-1.0mm high. They range from Early Carboniferous in the United States (Webster, unpubl. data) to the Permian. They are illustrated for comparison in future studies and to demonstrate the scope of the Callytharra echinoderm fauna.

Order CLADIDA Moore &Laudon, 1943
Suborder CYATHOCRININA Bather, 1899
Superfamily CYATHOCRINITOIDEA Bassler, 1938
Family CYATHOCRINITIDAE Bassler, 1938

Occiducrinus Webster, 1990

TYPE SPECIES
Occiducrinus australis Webster, 1990 from the Artinskian Wandagee Formation, Minilya River, W.A.; by original designation.

Occiducrinus australis Webster, 1990
(Fig. 11B-D)

Occiducrinus australis Webster, 1990:60, pl. 2, figs 1-3.

MATERIAL
QMF21427 from the third thick sandstone bed above the base of the Artinskian Wandagee Formation, east limb of syncline, approximately 150m north of the Minilya River, Coolkilya Pool area, Wandagee Station, Western Australia.

REMARKS
This cup was weathering out as associated disarticulated plates on a bedding surface which also yielded *Eoindocrinus praecontignatus* and *Calceolispongia abundans*. The reconstructed cup lacked the anal, the D radial and the orals; it is nearly identical in size with the holotype.

The proximal columnal showing the articulum provides information not preserved on the holotype. Crenularium narrow; culmina short, widely spaced; crenellae wide, flat base, bearing rudimentary short ridges and V-shaped protrusions along irregularly walled outer side. Areola three times width of crenularium. Disarticulated columnals should be easily recognised.

Family BARYCRINIDAE Jaekel, 1918

Barycrinid? indet.
(Figs 12, 22D)

MATERIAL
Figured specimens QMF21434, 21436 from QML760, QMF21435 from QML761, QMF21437 from QML757. Other material QMF21586 from QML757 and QMF21587 from QML760.

DESCRIPTION
Columnals circular, pentameres; latus gently convex; heteromorphic type I pattern; symplexy articulation. Crenularium 1/3 radius on small columnals, may be more on large columnals, projects into areola at pentamere boundaries on some specimens. Culmina irregular, medium width, wider distally, may divide isotomously once; new culmina may be inserted distally. Areola 1/3 radius on small columnals, may be less on large columnals, sloping inward, smooth. Axial canal strongly pentastellate; claustrum narrow, thin, wedge-shaped, forms base of areola. Cirri circular in section, short, tapering rapidly distally, not divided into pentameres; latus straight; articulum same as pentamere articulum; axial canal narrow, slightly dumb bell-shaped transversely.

REMARKS
All pluripentameres (up to 4.95cm length) and pluricolumnals of articulated pentameres were recovered as loose specimens. Weathering destroyed many morphologic features but especially the claustrum on pluripentameres. Differentiated weathering resulted in irregular wavy thickness on external surfaces of some columnals (Fig. 22D). Most of the larger specimens are part of the holdfast or distal parts of the stem. The robust size suggests they supported a sizeable crown. It is unknown if the pentameres extended to the cup.

Pentameric columnals are present on several inadunates and camerates of Ordovician through Devonian age (Moore & Jeffords, 1968). Middle

Mississippian *Barycrinus* from Iowa are the previously recognized youngest pentameric stems (Moore et al. in Moore & Teichert, 1978). We refer these specimens questionably to the Barycrinidae and illustrate them because they are easily recognizable, have potential as Permian index fossils in the Carnarvon Basin and extend the geographic and stratigraphic range of pentameric columnals.

Superfamily CODIACRINOIDEA Bather, 1890
Family STREBLOCRINIDAE Lane, 1967

Lampadosocrinus Strimple & Koenig, 1956

TYPE SPECIES

Dichostreblocrinus minutus Peck, 1936 from the Lower Carboniferous St. Joe Formation, USA.

Lampadosocrinus variabilis sp. nov.
(Fig. 13)

ETYMOLOGY

Latin *variabilis* variable; refers to the variation in shape of the oral circlet, and number of infrabasal plates.

MATERIAL

Holotype QMF21450 from QML757-761 undifferentiated, paratypes QMF21451 from QML759, QMF21452 from QML757-761, QMF21453 from QML757, QMF21454 from QML758, QMF21455-21459 from QML759 and other material QMF21566 (5) from QML757, QMF21567 (2) from QML758, QMF21568 (24) from QML759, QMF21569 (2) from QML760, QMF21570 (5) from QML757-761.

DIAGNOSIS

Oral plates of variable shape; theca inflated; basals tumid.

DESCRIPTION

Theca small, conical, subcylindrical to widely inflated, widest at or slightly below oral summit, height/width ratio 1.0-1.4, surface ornament of minute pits.

IBB 1-5, most commonly fused; circlet low, narrowly to moderately outflared, pentalobate to circular transversely, forming lower 1/2 of cup, 1/4 of theca, bearing small impressed circular stem facet. BB 5, with variable length to width ratio, wider than long, subequal to longer than wide, convex transversely and longitudinally, tumidity gentle to moderately strong, rarely projecting into a short spine. OO 5, roundly to sharply protruded at or barely below thecal summit, oral surface inflated to depressed centrally, sutures flush to elevated along mutual narrow ridges. CD oral largest, protuberance more rounded than others, separates BC and DE orals. Oral circlet forming 2/5 thecal height, with slightly concave summit, horizontal or slightly inflated, sutures align with basal suture, rotated slightly or in normal alternate position. BC and DE oral protuberances commonly slightly down and outflared, EA and AE oral protuberances normally subhorizontal. No anal plates, BC basal left shoulder summit slightly below CD right shoulder summit; all other basal summits align.

REMARKS

Variation among the 47 specimens studied reflects growth changes and intraspecific variation. Two changes with growth are height/width ratios of the oral plates. In general elongation of the theca progresses from subequal height and width in immature forms to height greater than width in adult forms. Ratios in a growth series of 4 specimens calculated as 1.0, 1.4, 1.06, 1.11, smallest to largest. Oral plates of immature specimens are commonly roundly protuberant, rarely pointedly protuberant, and lack the rimmed depression on the summit typical of larger specimens. In immature forms the five protuberances project above the summit slightly, forming a slightly depressed summit. With growth the rimmed depression develops on each of the orals while the central oral summit is normally gently inflated forming the highest point on the theca. On the largest individuals the summit is commonly horizontal.

Intraspecific variation is noted in the following features. Most specimens are inflated moderately with only a few specimens having mildly inflated subcylindrical walls above the infrabasals. The angle of outflaring to the protuberances on the orals is variable. Tumidity of the basals ranges from slight to moderate and rounded to elongate in outline; rarely the tumidity is a short sharpened projection or blunt spine. Sharpness of the oral tumidity varies from rounded to angular and directed subhorizontal to gently upflared.

Suborder POTERIOCRININA Jaekel, 1918
Superfamily SCYTALOCRINOIDEA Moore & Laudon, 1943
Family APHELECRINIDAE Strimple, 1967

Cosmetocrinus Kirk, 1941

TYPE SPECIES

C. gracilis Kirk, 1941 from the Mississippian of Indiana; by original designation.

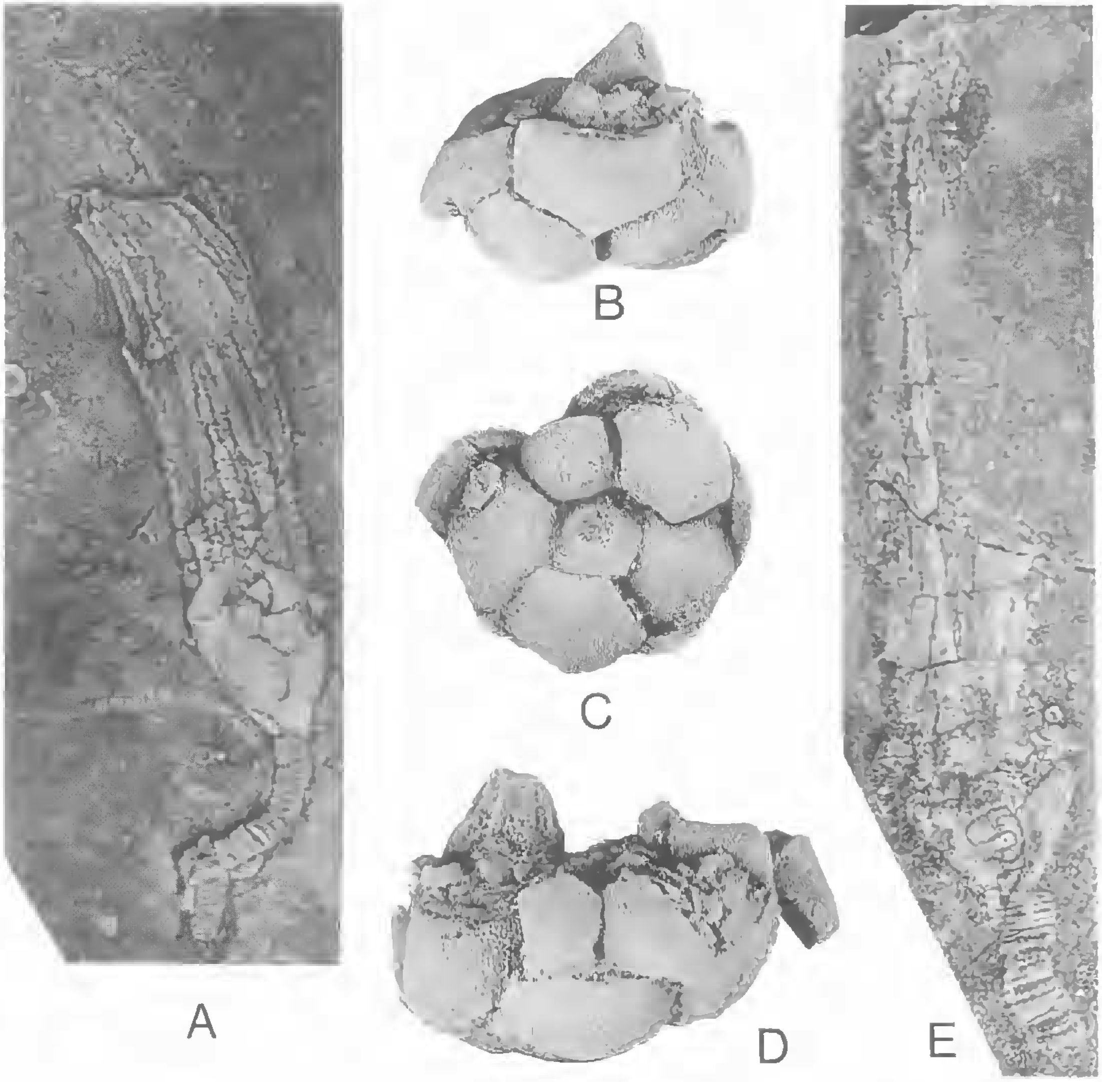


FIG. 14. A, *Cosmetocrinus? middalyaensis* sp. nov., posterior view of holotype UWAF113385, ×0.7. B-D, *Trautscholdicrinus* sp. A ray, basal and posterior views of WAM67.529, ×3. E, *Notiocatillocrinus callytharraensis* Webster, 1987, weathered crown showing cross-section of cup and tegmen, NMVP127202, ×1.1.

Cosmetocrinus(?) middalyaensis sp. nov.
(Fig. 14A)

ETYMOLOGY
For Middalya Station.

MATERIAL
Holotype UWAF113385 from QML770. Collected by John Williamson.

DIAGNOSIS
Right tube plate not in contact with the radianal.

DESCRIPTION
Crown tall (119mm), cylindrical (23.3mm wide maximum), plates smooth. Dorsal cup conical, flattened, approximately equidimensional, 22.6mm long, 22mm wide at summit, base flat, walls slightly convex proximally, slightly outflared distally. IBB 5?, large, 7mm long, 7mm wide, steeply upflared. BB 5, large, CD longer

(13.1mm) than wide (7.5mm), mildly convex transversely and longitudinally. RR 5, large, 7.8mm long, 7.8mm wide, mildly convex transversely and longitudinally. Radial facets plenary, sloping outward, with well developed transverse ridge and outer ligament pit; slight gape between radials and primibrachials. Anals 3, radianal narrow, in oblique position, adjoins C radial, BC and CD basal and anal X; anal X largest, 6.3mm long, 4.8mm wide, adjoining right tube plate, C radial, radianal, CD basal, D radial, and 2 tube plates, distal tip above radial summit; right tube plate nearly excluded from cup, only proximal tip below radial summit, not in contact with radianal. IBrr one per ray; in C and D rays, longer (8mm) than wide (6.6mm), constricted distally, strongly convex transversely, axillary. IIBrr, IIIBrr and IVBrr cuneate, strongly convex transversely. All branching isotomous. Second branching on IIBr8-10, one additional branching in some rays. Total number of arms exceeds 20 per ray if branching uniform in all rays. Pinnules small, slender. Anal sac tall, slender, mostly covered. Stem round transversely, heteromorphic, thin columnals, type II patterns for proximal 40mm, homeomorphic thick columnals distally; total of 130mm of stem preserved. Columnal latus convex, symplexy articulation. Non-cirriferous.

REMARKS

Radials of this species were described as inadunate radial #7 (Webster, 1987) based on loose radials found at Callytharra Springs approximately 250km to the south. *C.? middalyaensis* is widespread in the Carnarvon Basin and the radials are sufficiently distinct to be identified when disarticulated.

The crown is crushed in situ as it retains the arms and considerable length of the stem. Erosion has removed, but left the impression of, the distal 30mm of the arms. Generic assignment remains tentative because the A ray is not exposed to determine if branching occurs on the first primibrachial or a higher primibrachial as in *Paracosmetocrinus*. Some species of *Paracosmetocrinus* have a strongly cirriferous proximal stem, which is not present in *C.(?) middalyaensis*. The number of infrabasals is also uncertain as only one complete and one partial infrabasal are exposed. Their size and position suggests there are only three infrabasals on this form.

Crinoids associated on the slab are a weathered crown of *Texacrinus granulosus* sp. nov., disarticulated columnals of a camptocrinid and at least five unidentified crinoids. In addition several specimens of the spiriferid brachiopod *Fusispirifer carnarvonensis* Archbold & Thomas, 1987 and fenestrate bryozoans are present.

Elevation of the right tube plate until it is nearly eliminated from the cup is an advanced condition, suggesting a younger age than the Early Carboniferous age of previously described species (Moore & Teichert, 1978). Aphele-crinids were previously known only from the Lower Carboniferous of North America and Europe (Moore &Teichert, 1978).

Superfamily AGASSIZOCRINOIDEA Miller, 1889

Family AMPELOCRINIDAE Kirk, 1942

Spheniscocrinus Wanner, 1937

TYPE SPECIES

Spheniscocrinus spinosus Wanner, 1937 from the Permian of Timor; by original designation.

Spheniscocrinus australis sp. nov.
(Fig. 11A)

ETYMOLOGY

Latin *australis*, southern.

MATERIAL

Holotype crown CPC30682 from the Artinskian upper Bulgadoo Shale or lower Cundlego Formation, 7.5km on bearing 287° from Wandagee Homestead, Minilya 4 mile map sheet, Carnarvon Basin.

DIAGNOSIS

Ornament shagreen with small pits; sutures flush; spines on brachials without nodes.

DESCRIPTION

Crown small, low, outspreading laterally, estimated 60mm diameter; ornament of small depressions on very fine shagreen surface. Cup low bowl to discoid-shaped, 5.7mm wide, 2.2mm high (estimated), shallow apical pits. IBB 5, impressions small, probably subhorizontal. BB 5, small, convex transversely and longitudinally, unequal size; EA estimated 1.3mm long, 1.2mm wide; CD 2.1mm long (estimated), 2mm wide. RR 5, wider (1.8mm) than long (1.3mm), gently convex longitudinally, strongly convex transversely, thick, spreading laterally proximally resulting in wide gap between radials at summit. Radial facet plenary, slope steeply outward, thick, small gaps. Anals 3, in intermediate position. Radianal in oblique position intermediate in size. Anal X largest, strongly convex transversely, adjoins posterior basal. Right tube plate smallest, not in contact with

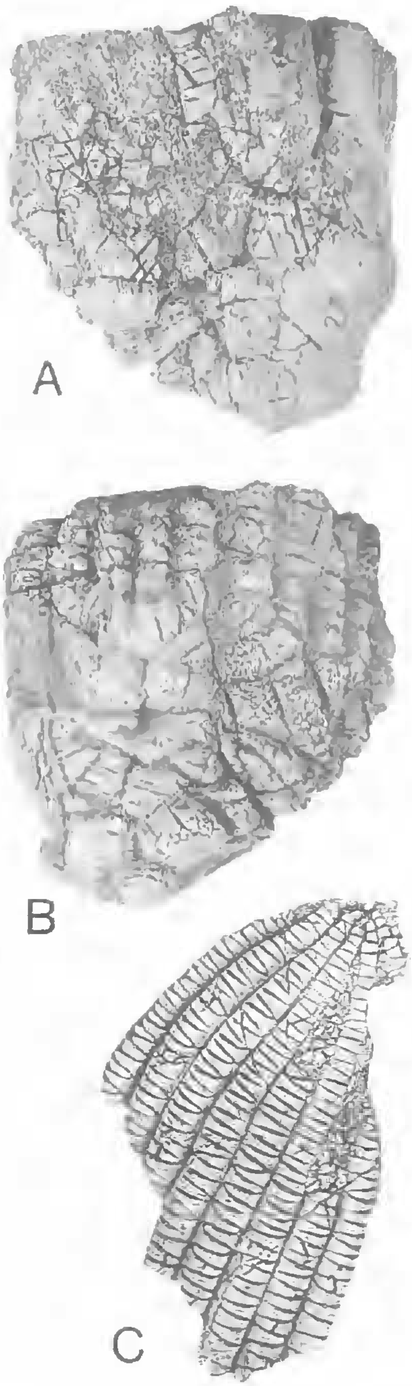


FIG. 15. *Minilyacrinus williamburyensis* sp. nov., posterior and B ray views of weathered holotype crown, WAM91.697, ×1. C, fragmentary set of arms, UWAF113504, ×1.5.

radianal, proximal end barely below radial summit, admedial to anal X, barely visible in lateral view. IBrr 2 per ray, rectilinear, wider than long, thick, straight longitudinally, strongly convex transversely; axillary IBrr$_2$ constricted slightly proximally. IIBrr and IIIBrr cuneate, wider than long, thick, strongly convex transversely. All branches isotomous on IBr$_2$ and IIBr$_8$, minimum 4 arms per ray. Pinnules moderately large but not ramules, one per brachial on alternate sides of arm. Stem and tegmen not known.

REMARKS

This crown is inverted with the arms splayed outward on the substrate. The stem, infrabasal circlet and parts of most basals are not preserved but impressions of the inner side of the infrabasals and basals are moderately clear. The anal series extending into the base of the anal tube or sac is large, nearly the size of the base of the arms.

Spheniscocrinus was defined by Wanner, 1937, as having only one anal in the cup, however, the holotype and only specimen appears to be slightly distorted in the base of the C ray and adjacent anal series. It may have an intermediate arrangement of the anals as described above.

This is only the second member of the genus and is distinguished from the type species by the fine shagreen ornament, flush sutures and lack of nodes or spines on the brachials. Generic distribution is extended to Western Australia strengthening the link between Timorese and Western Australian Permian faunas.

Superfamily DECADOCRINOIDEA Bather, 1890
Family DECADOCRINIDAE Bather, 1890

Trautscholdicrinus Yakovlev & Ivanov in Yakovlev, 1939

TYPE SPECIES

Trautscholdicrinus miloradowitschi Yakovlev & Ivanov in Yakovlev, 1939, Upper Carboniferous Moscow Basin; by original designation.

Trautscholdicrinus sp.
(Fig. 14B-D)

MATERIAL

Partial crown WAM67.529, from the Artinskian Fossil Cliffs Formation, north branch Irwin River, Perth Basin. Found by Mrs J. White.

DESCRIPTION

Cup medium bowl-shaped, shallow basal invagination, walls subvertical, fine granular ornament. IBB 5, small, equidimensional (2.0mm) kite-shaped, slightly upflared, not visible in lateral view. BB 5, hexagonal, wider (5.8mm) than long (5.0mm), moderately convex transversely, strongly convex longitudinally, proximally form base of cup, distally subvertical forming nearly half cup height, slightly tumid. RR 5, wider (5.7mm) than long (3.4mm) slightly convex longitudinally, moderately convex transversely. Radial facet plenary, sloping gently outward, bearing transverse ridge, outer ligament pit and furrow, and wide shallow muscle areas adorally. Anals 3, in intermediate position. Radianal largest, pentagonal, adjoins C radial, BC and CD basals, anal X and right tube plates. Anal X pentagonal, truncated CD basal, adjoining one tube plate distally. Right tube plate not preserved. proximal end barely below radial summit. A ray IBr1 axillary, strongly convex transversely. Distal brachials slightly cuneate, strongly convex transversely, bearing one pinnule each distally. Stem impression round.

REMARKS

The cup is crushed from compaction but plates are well preserved. The infrabasal circlet is not visible in lateral view and sutures appear slightly impressed because the tumidity of the basals projects above them. This is the second crinoid reported from the Fossil Cliff Formation after *C. digitata* (Teichert, 1949). The specimen is of insufficient quality to serve as a type. Radials like these occur in the disarticulated ossicles at Callytharra Springs.

Superfamily CROMYOCRINOIDEA Bather, 1890

Family CROMYOCRINIDAE Bather, 1890

Minilyacrinus gen. nov.

TYPE SPECIES

Minilyacrinus williamburyensis sp. nov.

ETYMOLOGY

For the Minilya River.

DIAGNOSIS

Cup bowl-shaped, with single anal; arms uniserial, cuneate, numbering 20.

Minilyacrinus williamburyensis sp. nov.

(Fig. 15)

ETYMOLOGY

For Williambury Station.

MATERIAL

Holotype WAM91.697 from an undesignated locality on Williambury Station. The specimen was enclosed in a quartz and mica bearing grainstone of the Callytharra Formation. It probably came from the vicinity of Donnelly's Well or other exposures of the Callytharra Formation in the eastern line of the Gooch Range in the southwestern part of Williambury Station. One partial set of arms (UWA) from the eastern line of the Gooch Range along the Minilya-Williambury Station road.

DESCRIPTION

Crown moderately large, 42.8mm long incomplete, average 13.1mm wide, cylindrical. Anal sac small cylindrical, formed of eight rows of plates. Cup moderately large, 13.9mm high, 23.1mm wide at summit, bowl-shaped; walls gently outflared distally; moderately deep basal invagination (7.1mm diameter); unornamented; sutures flush. IBB small, covered by proximal columnals, confined to basal invagination, probably downflaring. BB 5, large, slightly wider (8.8mm) than long (7.8mm), strongly convex longitudinally, moderately convex transversely, proximal ends within basal invagination, forming basal plane of cup; CD basal symmetrical, truncated distally for adjoined radianal. RR 5, large, wider (14.7mm) than long (9.7mm), moderately convex transversely, mildly convex longitudinally. Radianal longer (8.6mm) than wide (6.5mm), slightly over half above radial summit, adjoined distally by one tube plate. Radial facets plenary, sloping gently outward, moderate gape between radials and primibrachials. IBrr one per ray, wider (14.5mm) than long (8.1mm), moderately convex transversely, mildly convex longitudinally, axillary. IIBrr 2 per ray, wider (8.4mm) than long (4.1mm), strongly convex tranversely. IIIBrr wider than long, slightly cuneate, strongly convex transversely, thick, pinnulate. Ambulacral groove narrow, deep. Branching isotomous, 20 arms. Stem heteromorphic; columnals circular transversely, lumen pentagonal, symplexy articulation

REMARKS

The partial crown has been deeply weathered on exposed surfaces, the distal part of the arms and anal sac are lost, slight crushing occurred oblique to the A-CD symmetry plane, and arms adjacent to the anal series have been disarticulated in part. Weathering along the flush sutures of the cup plates and into cleavage planes in the calcite plates appear as deep impressions. A small portion of the B and C rays, including radials and adjacent basals were enclosed in matrix and unweathered.

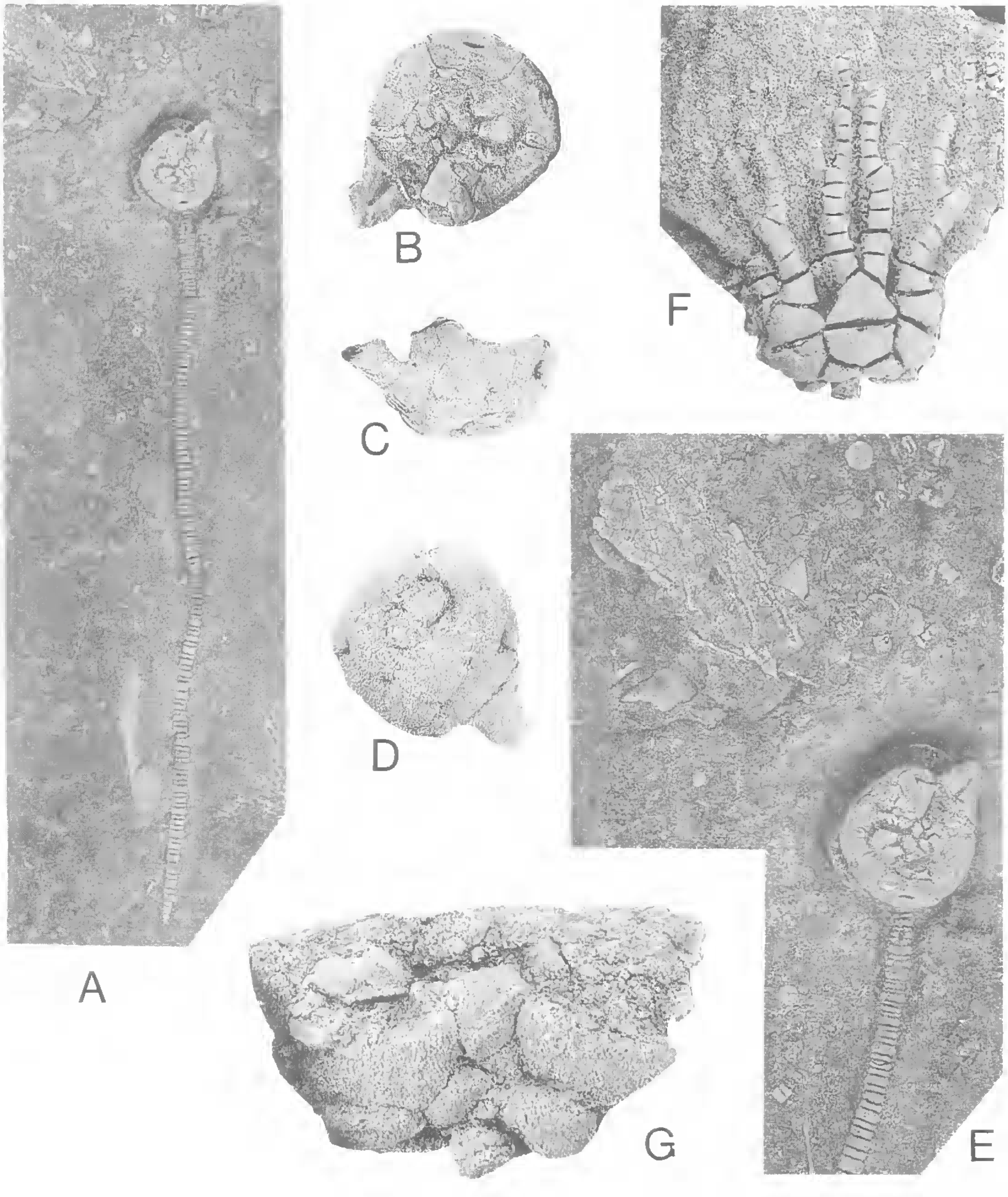


FIG. 16. *Texacrinus goochensis* sp. nov. A-E, paratype UWAF115099. A, weathered crown showing attached stem, ×1. B-D, oral, posterior and basal views of dorsal cup with attached primibrachial, ×3. E, enlargement of part of A showing parts of arms to upper left and directly above cup and change in heteromorphic patterns, proximally type II to distally Type I, ×2. F,G, lateral and posterior views of holotype crown UWAF 113387, F ×2; G ×3.5.

Removal of the matrix exposed the lack of ornamentation and flush sutures.

The partial set of arms show the tapering distal arm tips of slight cuneate shapes typical of the cromyocrinids. Thickness of the plates, narrow ambulacral grooves, strong external convexity and slight cuneate shape of the brachials is similar to that of uniserial brachials in the Cromyocrinidae. However, cup plates lack the impressed sutures typical of smooth plated cromyocrinids with uniserial arms (Webster, 1981).

The single anal and multiple arms reflect an advanced evolutionary condition. This is the first cromyocrinid bearing uniserial arms to be recognised with more than 10 arms, whereas many biserial armed cromyocriniods have 12 to 19 arms (Webster, 1981).

Evolution of *Minilyacrinus* is uncertain, perhaps through *Cromyocrinus*, *Goleocrinus* or *Mooreocrinus* by increase in arm number, reduction of the number of anals in the cup and increase in depth of the basal invagination. Evolution from *Moapacrinus* would only require increase in arm number.

The Cromyocrinidae is an Early Carboniferous to Early Permian family with greatest generic and specific diversity in the Late Carboniferous (Webster, 1981). They have been reported from North and South America and Eurasia. Webster (1981) considered all Permian forms from Timor, Russia and India previously referred to the cromyocrinids to belong to an unnamed genus or genera of non-cromyocrinid stock. Only two cromyocrinids, *Moapacrinus* and an unnamed genus, are of Permian age. Both are from the southwestern United States, have only one anal, and the 10 arms are uniserial on *Moapacrinus* but unknown on the unnamed genus (Webster, 1981).

Minilyacrinus is the first cromyocrinid from Western Australia. The partial set of 10 arms identified as Poteriocrinidae gen. ind. et. spec. nov. ind. (Wanner, 1949, pl. 3, fig. 31) from Timor probably belongs to a cromyocrinid.

Superfamily ERISOCRINOIDEA Wachsmuth & Springer, 1886

Family GRAPHIOCRINIDAE Wachsmuth & Springer, 1886

Tapinocrinus Webster, 1987

Type Species

Tapinocrinus macurdai Webster, 1987 from the Artinskian Callytharra Formation, W.A.; by original designation.

Tapinocrinus spinosus Webster, 1990
(Fig. 11E)

Material

WAM91.696 from the Wandagee Formation, north side Minilya River, Coolkilya Pool area, Wandagee Station, Western Australia; collected by H. Coley.

Remarks

A second specimen of *Tapinocrinus spinosus*, 42.5mm long, 20.1mm wide, shows the delicate shape and pointed apex of the fully enclosed crown. A very fine shagreen ornamentation is preserved along the arm sutures on brachials of the D ray. This is not preserved on the specimen reported by Webster (1990).

Superfamily TEXACRINOIDEA Strimple, 1961
Family TEXACRINIDAE Strimple, 1961
Texacrinus Moore & Plummer, 1940

Type Species

Texacrinus gracilis Moore & Plummer, 1940 from the Middle Pennsylvanian, Millsap Lake Formation, Texas; by original designation.

Texacrinus goochensis sp. nov.
(Fig. 16)

Etymology

For the Gooch Range.

Material

Holotype UWA F113387, a crown collected by Chris Hearne; paratype UWA115099 collected by John Williamson from QML770.

Diagnosis

Ornament granulose.

Description

Crown small, weakly outflared, anal sac unknown, granulose ornament on cup plates and proximal brachials. Dorsal cup small, low bowl-shape, nearly three times wider than high, widest at radial summit, moderately deep basal invagination, sutures flush to gently impressed, moderate pits at apices of basals and radials. IBB small, confined to basal invagination, covered by proximal columnals, probably downflared. BB 5, wider than long, tumid, forming walls of invagination proximally, basal plane of cup medially, lower part of gently outflaring walls of cup distally, distal tip incurved; posterior basal may be

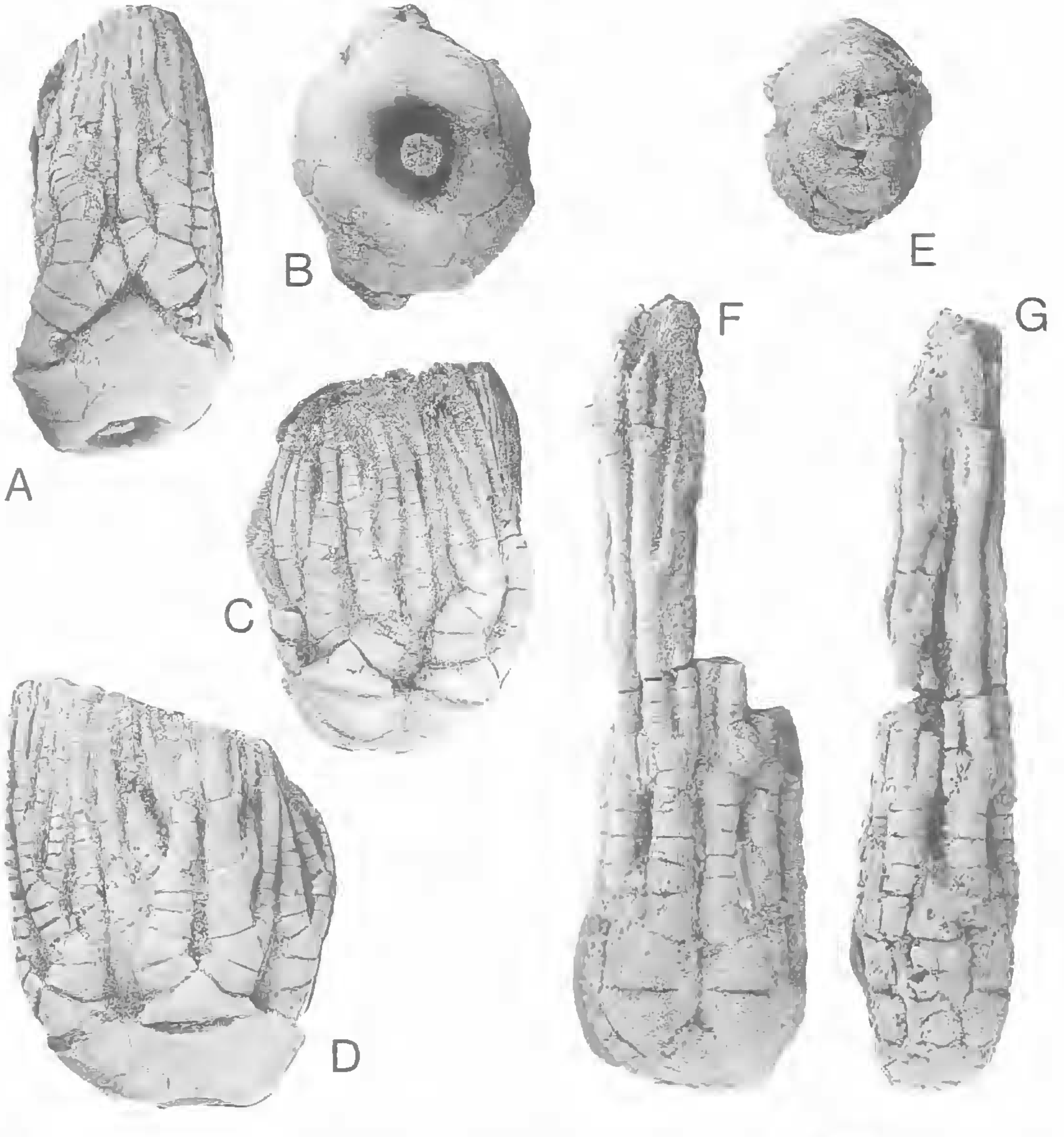


FIG. 17. A-D, *Texacrinus gascoynensis* sp. nov., posterior, basal, BC interray and B ray views of holotype WAM91.698, ×1. E-G, *Texacrinus hardmanensis* sp. nov., basal, BC interray and posterior views of holotype CPC30683, ×1.5.

truncated distally for anal X. RR 5, approximately twice as wide as long, mildly convex transversely and longitudinally, tumid, outflared. Radial facets plenary, sloping outward gently, with well developed transverse ridge, outer ligament pit and muscle fields. Anals 3 in primitive or modified primitive arrangement, variable in relative sizes. Radianal pentagonal or hexagonal, may or may not adjoin D radial, longer than wide. Anal X longer than wide, 0.5-0.67 below radial summit, adjoining one tube plate distally. Right tube plate small, proximal 1/3 below radial summit, adjoining one tube plate distally. IBrr one per ray, wider than long, constricted distally, strongly convex transversely, unequal in length (A ray longest), axillary. IIBrr to VIBrr slightly cuneate, equidimensional to wider than long, branching on 4th or 5th brachial in each series. First branch

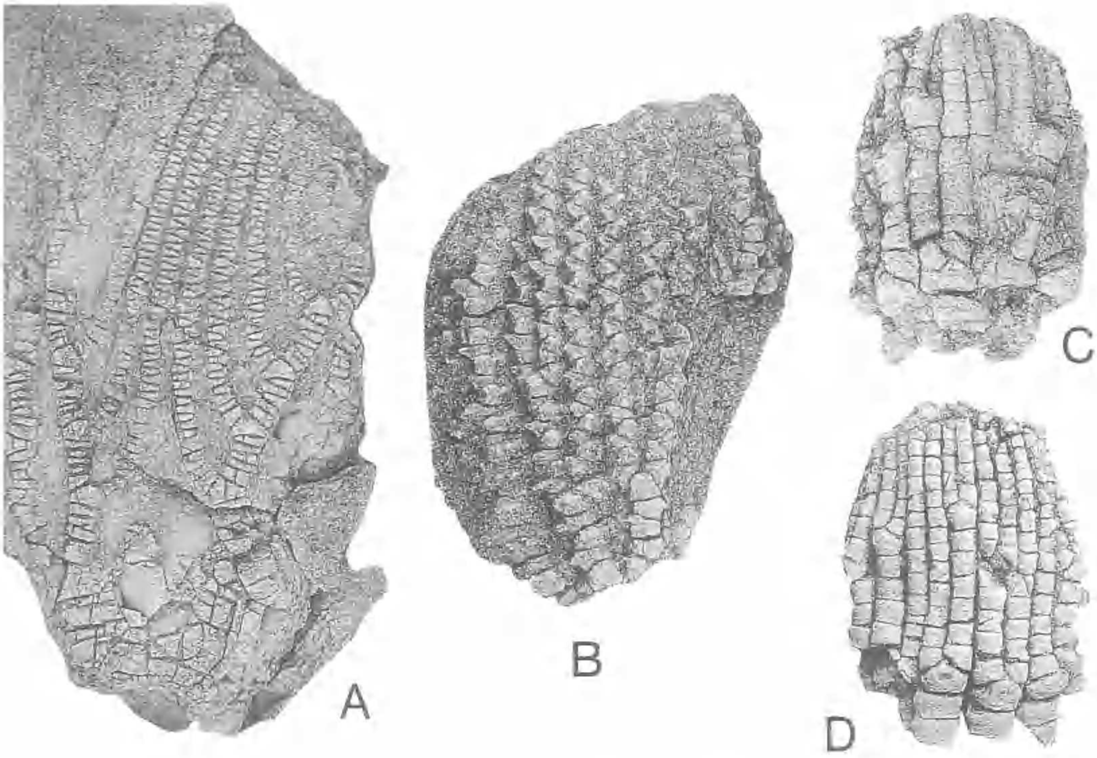


FIG. 18. A, *Galateacrinus australis* sp. nov., anal view of holotype UWAF113388, ×1. B, Family and genus indet., lateral view of set of arms QMF21469, ×1.6. C,D, Timorechinid indet., lateral views of set of arms, QMF21468, ×1.6.

isotomous, thereafter heterotomous bi-exotomous, 30 to 50 arms. Stem round, columnals thin heteromorphic type II pattern proximally, thicker heteromorphic type I pattern distally, latus convex, non-cirriferous, lumen pentagonal.

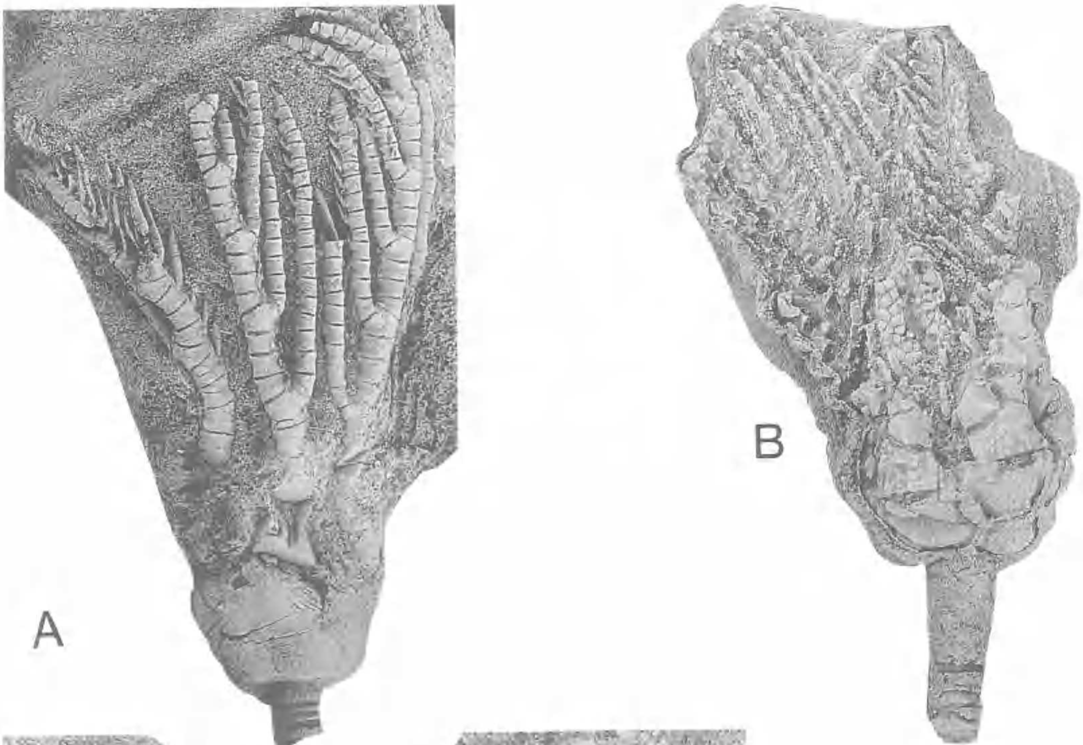
MEASUREMENTS (mm)

	Holotype UWA113387	Paratype UWA113385
Crown length	29.9 (incomplete)	35.0
Crown width	32.8 (at IIIBr)	-
Cup height	4.3	3.6
Cup width	11.8 (average)	9.9
Basal length	2.6	2.6
Basal width	3.6	3.6
Radial length	2.9	3.3
Radial width	6.0	5.9
IBr1 length	4.4	3.3
IBr1 width	6.0	4.5
Diam.proximal columnal	2.2	2.3

REMARKS

The holotype is a crushed crown lacking the distal parts of the arms with the anals in primitive arrangement; the radianal is in oblique position not in contact with the D radial. Weathering of the paratype has removed all except one primibrachial and distal parts of the arms of two rays. The paratype has anals in a slightly advanced arrangement; the radianal adjoins the D radial separating anal X from the CD basal. The slightly advanced arrangement of the anals has been reported in all species previously assigned to the genus suggesting that it has been a fairly stable genetic character since the middle Pennsylvanian.

Texacrinus has been reported from middle Pennsylvanian to Early Permian strata of the United States (Webster, 1973). Variables within the family are degree of suture impression (slight to moderate), depth of basal invagination (slight to deep), development of apical pits (not present to moderately deep), cup shape (slightly globose to weakly outflared low to medium bowl), and brachial form (nearly flat to strongly convex transversely; rectilinear to slightly cuneate, very



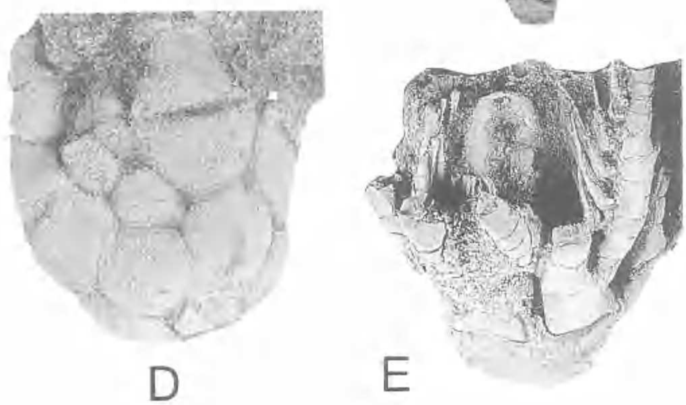


FIG. 19. *Skaiocrinus granulosus* Webster, 1990. A, C ray view of WAM91.669 showing bi-exotomous branching pattern, ×1.6. B, lateral view of WAM91.668 showing recurved anal tube and interior of some arms, ×1.6. C,D, lateral and posterior views of WAM91.694, ×1.6; note anal tube on interior of lateral view. E, lateral view of WAM91.671 showing recurved anal tube and proximal pinnules, ×1.3.

short to short). Where known, the arms branch bi-exotomous after an initial isotomous division. We consider *T. interruptus*, *T. irradiatus* and *T. compactus* named by Strimple (1952) and all from the Francis Shale of Oklahoma to be one species showing slight to moderate variation in many of the cup features listed above. We select *T. irradiatus* to be the senior synonym because the holotype is a more complete individual and intermediate in the range of variation.

Texacrinus goochensis extends the geographic range of the genus to Western Australia and is the first species named with granulose ornament.

Texacrinus hardmanensis sp. nov.
(Fig. 17E-G)

ETYMOLOGY

For Mount Hardman.

MATERIAL

Holotype CPC30683, a partial crown, from the Tatarian Cherrabun Member, Hardman Formation, at Mt. Hardman, Canning Basin. BMR localities KLB 11.

DIAGNOSIS

Anals in intermediate position with proximal tips of anal X and radianal below summit; arms elongate.

DESCRIPTION

Crown elongate (68.5mm, slightly incomplete), cylindrical, widest at radial summit, no arm girdle, fine vermiform to granular ornamentation on all plates, crushed slightly normal to plane of symmetry. Cup bowl-shaped, wider (16.3mm average) than high (9.7mm), base invaginated, sutures shallowly impressed, shallow apical pits. IBB 5?, covered, small, probably downflared, not visible in lateral view. BB 5, wider than long (C basal 6.4mm wide, 5.9mm long), gently convex transversely, moderately convex longitudinally, forming base of cup proximally; CD basal truncated distally for radianal. RR 5, wider (8.9mm) than long (6.3mm), gently convex. Radial facets plenary, subhorizontal, narrow gape. Anals 3, in intermediate position. Radianal large, 4.4mm long, 3.8mm wide, in line of radials. Anal X and right tube plate subequal, 2.5mm wide, 2.4mm long, proximal ends barely below radial summit, each adjoining one tube plate distally. IBrr one per ray, wider (9.7mm) than long (5.2mm), slightly convex longitudinally, moderately convex transversely, axillary. IIBrr, IIIBrr, IVBrr and VBrr rectilinear, wider than long, strongly convex transversely, branch on 5th to 8th brachial in each series. First branching isotomous, thereafter heterotomous bi-exotomous, minimum of 10 arms per ray. Pinnules slender, borne by alternating branchials. Stem pentagonal.

REMARKS

The crown was enclosed in a quartz wackestone. It had been crushed slightly by compaction. Irregular calcite cementation of the matrix and hydrous iron oxide cementation and replacement of plate edges along some sutures made preparation difficult.

The specimen is an advanced member of *Texacrinus* with the most elongate slender arms known within the genus. It probably evolved from *T. goochensis* by elongation of the brachials and modification of the anals. It is one of the three youngest known Palaeozoic crinoids.

Texacrinus gascoynensis sp. nov.
(Fig. 17A-D)

ETYMOLOGY

For the Gascoyne River.

MATERIAL

Holotype WAM91.698, from the Artinskian Cundlego or Wandagee Formation on Jimba Jimba Station, Carnarvon Basin. Exact horizon and locality unknown.

DIAGNOSIS

Radial facets peneplenary; anals in a near advanced position with only proximal most tips of anal X and right tube plate below radial summit.

DESCRIPTION

Crown, robust, moderately short, 56.9mm long, average 37.4mm wide, cylindrical. Cup moderate bowl-shaped, large, 10.0mm high, average 33.7mm wide; basal invagination 12.4mm diameter, 4.0mm deep; sutures flush; shagreen ornamentation. IBB 5?, covered, small, confined to basal invagination, probably downflared. BB 5, large, wider (12.9mm) than long (10.0mm), strongly convex longitudinally, mildly convex transversely, forming basal plane of cup; CD basal truncated distally for radianal. RR 5, large, nearly twice as wide (17.6mm) as long (9.0mm), gently convex longitudinally and transversely, mildly outflaring. Radial facets peneplenary with narrow notch, sloping gently outward. Radianal large, slightly wider (8.1mm) than long (7.8mm), adjoined distally by anal x and right tube plate proximal most tips of which are below radial summit. IBrr one per ray, pentagonal, wider

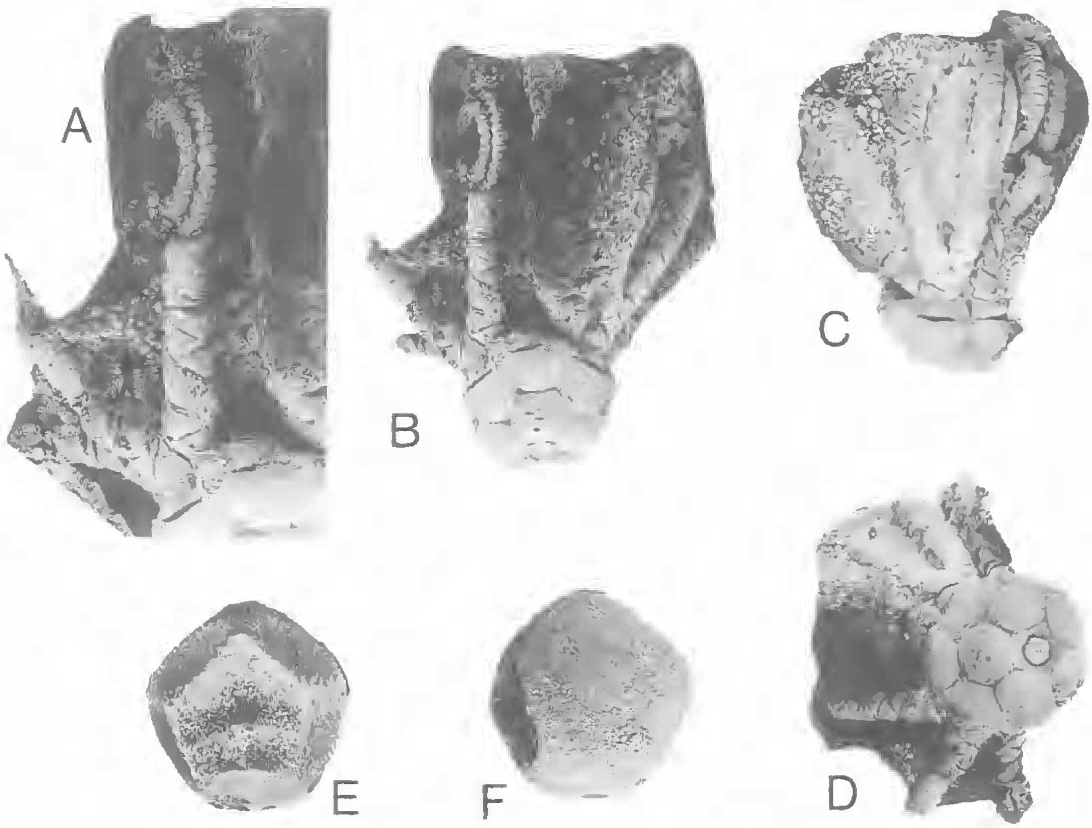


FIG. 20. *Cymbiocrinus cherrabunensis* sp. nov. A, D ray arm showing cuneate brachials, ×1. B-D, posterior, C ray and basal views of holotype CPC30684, ×0.75. E,F, internal and external views of paratype basal QMF21480, ×2.

(14.5mm) than long (6.7mm), constricted distally, strongly convex transversely, gently convex longitudinally, axillary. IIBrr to VIIBrr rectilinear, wider than long, moderately convex transversely, straight to gently convex longitudinally; brachials number 2 IIBr; 3 IIIBr, 4 IVBr, 4 or 5 VBr, 5 VIBr, 3 or 4 VII Br, unknown number of VIII Br. First branching isotomous, all others heterotomous biexotomous; minimum 14 arm per ray. Anal sac unknown, probably short. Stem round transversely, heteromorphic. Latus strongly convex; axial canal round.

REMARKS

This nearly complete crown is replaced with hydrous iron oxides and weathered a deep ferruginus red. It was embedded in a medium-grained quartz wackestone and slightly compressed normal to the A-CD axis. The radial facets are peneplenary and distinguish it within the genus. If the base of the anal X and right tube plate were any higher they would be out of the cup and the form would be considered to have a single anal.

Consideration was given to designating a new genus based on the combination of the peneplenary facets and near single anal condition. Until the single anal condition is established we prefer to retain this form in *Texacrinus*.

Galateacrinus Moore, 1940

TYPE SPECIES

G. stevensi Moore, 1940 from the middle Pennsylvanian Oologah Limestone of Oklahoma; by original designation.

Galateacrinus australis sp. nov.

(Fig. 18A)

ETYMOLOGY

Latin *australis*, southern.

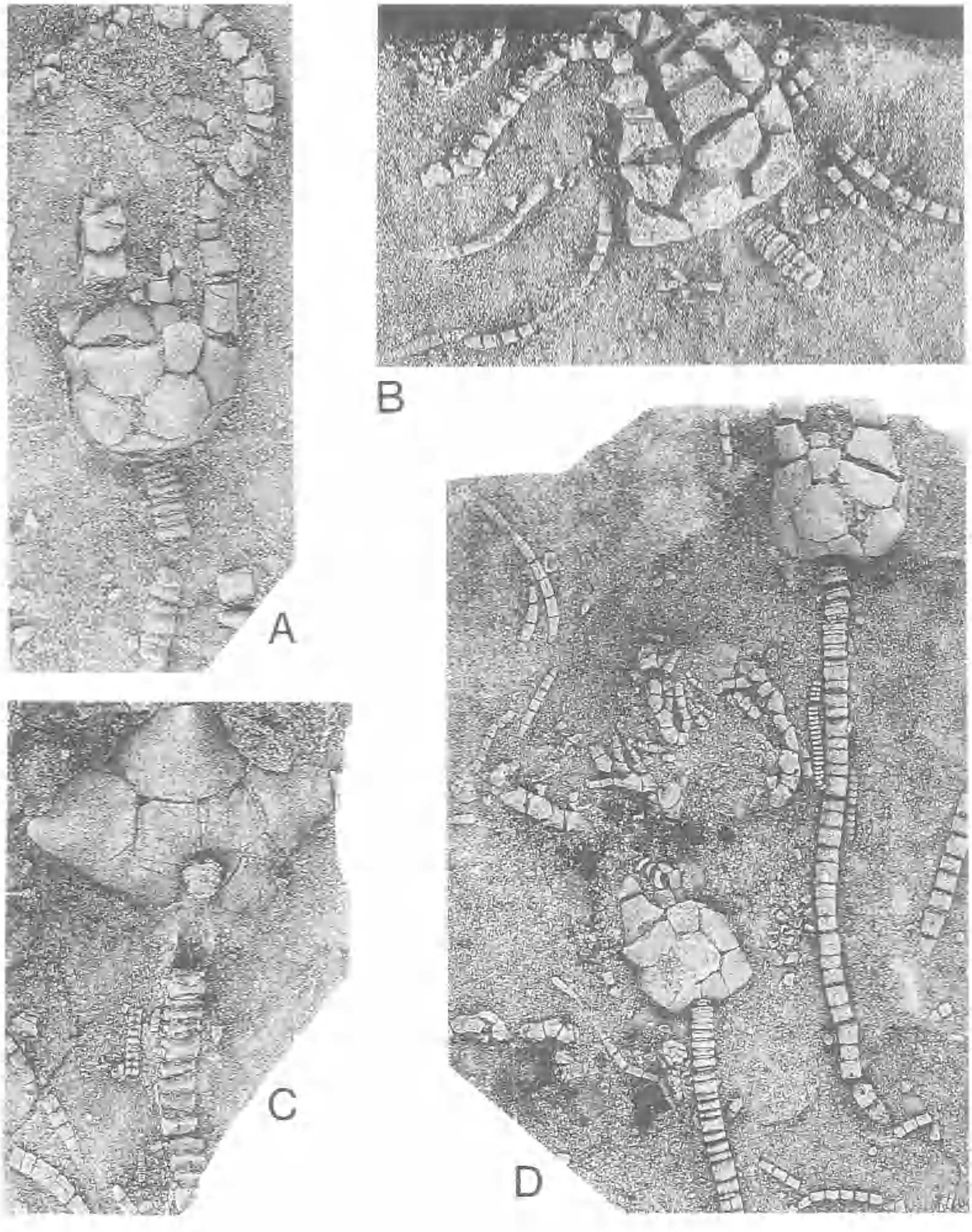


FIG. 21. *Jimbacrinus donnellyensis* sp. nov. A, posterior view of holotype CPC30685, ×4. B, lateral view of weathered paratype crown with arms splayed CPC30690, ×3. C, oblique view of infrabasal circlet and basal invagination of paratype CPC30686 on same slab as A, ×3.5. D, posterior views of paratypes CPC30687 (right) and CPC30688 (left) with *Stomiocrinus merlinleighensis* sp. nov. paratypes CPC30674 (to left of stem, 0.5cm below base of CPC30688) and CPC30675 (extreme bottom right corner), ×3.

MATERIAL
Holotype UWAF113388 from QML770.

DIAGNOSIS
Cup low bowl-shaped, lacking radial notches; brachials very short, locally becoming biserial within the uniserial arms.

DESCRIPTION
Crown tall (85.9mm incomplete) moderately outflaring (55.3mm wide at IBr1), anal sac stout. Dorsal cup low bowl-shape, nearly discoid, twice as wide (33.3mm maximum) as high (16mm diameter); sides widely outflaring; wide deep basal invagination (9.9mm); coarse vermiform(?) ornamentation; sutures weakly impressed. IBB restricted to invagination, probably downflared, not exposed if preserved. BB 5, large, CD 8.8mm long, 10.2mm wide, moderately convex longitudinally, gently convex transversely, proximal ends in basal invagination, widely outflared distally, forming basal plane of cup; CD basal truncated distally for adjoining anal X. RR 5, large, wider (15.5mm) than long (9.6mm), outflared widely; radial facets plenary, sloping strongly outward. Anals 3, primitive arrangement, distal 1/3 of anal X and right tube plate above radial summit. Radianal pentagonal, in oblique position, slightly longer (7.9mm) than wide (6.7mm); adjoining C radial, BC and CD basals, anal X and right tube plate. Anal X hexagonal, longer than wide (8.5x6.2mm), adjoins one tube plate distally. Right tube plate hexagonal(5.5x5.5mm). IBrr 1/ray, wider than long (15.5x6.2mm), moderately convex transversely and longitudinally, axillary. IIBrr to VIBrr strongly convex transversely, wider than long, cuneate with local biserial brachials. First branch isotomous, thereafter heterotomous bi-exotomous. Second branching on IIBrr4 or 5, third through sixth branch on 6th to 8th brachial in the series; 12 arms per ray. Pinnules, anal sac and column not preserved.

REMARKS
Only the C and D rays and adjoining parts of the dorsal cup are exposed and perhaps the only parts preserved. Its lack of radial notches and possession of cuneate brachials leave it transitional between the Texacrinidae (lacking radial notches with rectilinear to cuneate brachials), and the Galateacrinidae (with radial notches and cuneate brachials). The radial notches of the Galateacrinidae are formed by the very bulbous nature of the radials as the facets are actually plenary but adoral of the aboreal tumidity. Thus the Galateacrinidae are separated from the Texacrinidae on the shape of the cup, discoid vs low bowl respectively, not the length of the radial facet as the presence of radial notches tends to imply. We question if this is of sufficient difference to justify family separation.

This is the first record of a *Galateacrinus* in Australia. The genus has previously been reported only from the middle Pennsylvanian to Early Permian of the United States (Webster, 1973, 1977, 1986). The low bowl shaped cup, lack of radial notches and short brachials which locally become biserial readily distinguish *G. australis* from all other species of the genus.

Skaiocrinus Webster, 1990

TYPE SPECIES
Skaiocrinus granulosus Webster, 1990 from the Artinskian Wandagee Formation, Minilya River; by original designation.

Skaiocrinus granulosus Webster, 1990
(Fig. 19)

Skaiocrinus granulosus Webster, 1990:66, pl.2, figs 15-17.

MATERIAL
Cup WAM91.684; 6 partial crowns, WAM91.668, 91.669, 91.671, 91.692, 91.694, 91.696 and 3 sets of arms WAM91.670, 91.691, 91.693 from the Artinskian Wandagee Fmn, Minilya River, collected by H. Coley.

REMARKS
Several morphological features not visible or showing variation not recognisable on the original study material (Webster, 1990) are shown on the new specimens. Cup morphology is quite consistent with the exception of the width of the radial facets. On the holotype they are nearly plenary but must be considered peneplenary, whereas they are plenary or very nearly plenary with slight variation on all new specimens. Arms may branch up to 8 times (WAM91.692), resulting in 9 arms in one half ray and 90 arms for the crown if branching is uniform and maximum in all rays. Pinnules are very slender, taper slightly until the distal termination, have a medial longitudinal ridge, begin on the first secundibrach, and contain 9 plates in proximal pinnules. The slender tegmen is formed of small polygonal plates with flush sutures, no appearant transverse or longitudinal alignment of plates and is recurved. The column is heteromoprhic Type II pattern.

Based on the peneplenary radial facets, Webster (1990) assigned *Skaiocrinus* to the

Pachylocrinidae noting exotomous arm braching and similarity to the Texacrinidae. The genus is here transferred to the Texacrinidae because most of the new specimens show plenary facets.

No formation was known for the original study material. New specimens are from the Wandagee Formation, in a calcareous siltstone to medium-grained quartz wackestone. Cementation is generally weak but may include hydrous iron oxides which are difficult to remove when preparing specimens. Natural weathering exposed most of the features described above.

Family CYMBIOCRINIDAE Strimple & Watkins, 1969

Cymbiocrinus Kirk, 1944

TYPE SPECIES

Cymbiocrinus romingeri Kirk, 1944 from the early Chesterian St. Genevieve Limestone of Alabama; by original designation.

REMARKS

The Cymbiocrinidae may be divided into 2 groups with differing arm structures *Cymbiocrinus, Aenigmocrinus, Oklahomacrinus* and *Allosocrinus*, have cuneate brachials. *Lecobasicrinus, Aesiocrinus, Paracymbiocrinus* and *Proallosocrinus* have rectilinear brachials. Both groups appear in the Chesterian and range into the Virgilian in the United States. They probably had differing ancestral lineages and may represent different families. Additional investigation of the Cymbiocrinidae is required to properly resolve these problems.

Cymbiocrinus cherrabunensis sp. nov. (Fig. 20)

ETYMOLOGY

For the Cherrabun Member.

MATERIAL

Holotype, CPC30684, a crown from the Tatar-ian Cherrabun Member, Hardman Formation, east side of Mt Hardman, Canning Basin. Coll. J.M.Dickins. Paratype QMF21480 from QML 772.

DIAGNOSIS

Primanal large; 11 arms incurled distally.

DESCRIPTION

Crown 72mm long (arms curled distally), 75mm wide, inflated pear-shaped with incurled distal arms, no surface ornament. Cup medium bowl-shaped, wider (27.3mm) than high (11.8mm), walls outflared, base shallowly invaginated, sutures impressed, moderately deep apical pits. IBB 5, small, kite-shaped, 4.8mm long, 4.7mm wide, downflared, not visible in lateral view of cup. BB 5, large, 10.0mm long, 10.8mm wide, inflated, moderately convex transversely and longitudinally. RR 5, wider (14.3mm) than long (8.8mm), outflared, gently convex transversely and longitudinally. Radial facet plenary, bearing transverse ridge and outer ligament pit, slightly gaped. IBrr two per ray, moderately convex transversely, constricted distally. IBr_1 trapezoidal, wider (14.3mm) than long (3.7mm). IBr_2 triangular, 6.6mm wide 5.3mm long, axillary. All other brachials, unless axillary, strongly cuneate, bearing one slender pinnule each on alternate sides of arm. Arms 11? all branching isotomous. Proximal columnal pentagonal, 4.5mm diameter; latus convex. Crenularium narrow, culmina short, coarse. Areola wide, flat. Axial canal subpentagonal.

REMARKS

Assignment to *Cymbiocrinus* is based on cup shape, single anal, cuneate brachials, and branching on the second primibrachial. A third arm on the C ray (branching on the first secundibrachial abanally) is not typical of the genus. It is uncertain if this represents an evolutionary development or a variant. The bulbous basals show affinity to the calceolispongiid, *Jimbacrinus*, however the calceolispongiids have inflated basals, 5 atomous arms and most commonly a vestigal stem.

Hydrous iron oxides have replaced all plates and the crown is embedded in a coarse-grained quartz wackestone. The delicate arms are incurl-ed distally but visible in the natural weathered specimen. It is interpreted to have lived in or near the burial site on a sandy substrate.

Family TIMORECHINIDAE Jaekel, 1918

Timorechinid gen. indet. (Fig. 18C,D)

MATERIAL

QMF21468 a partial set of arms, QML770.

REMARKS

A small incomplete set of arms (25.0mm long) with 3 series of brachials shows 2 isotomous branchings. Brachials are wider than long proximally, equidimensional medially, longer than wide distally, strongly convex externally, and slightly cuneate. Axillary brachials (5-7 in middle series) have a central upward and outward directed short spine. Most spines are broken off

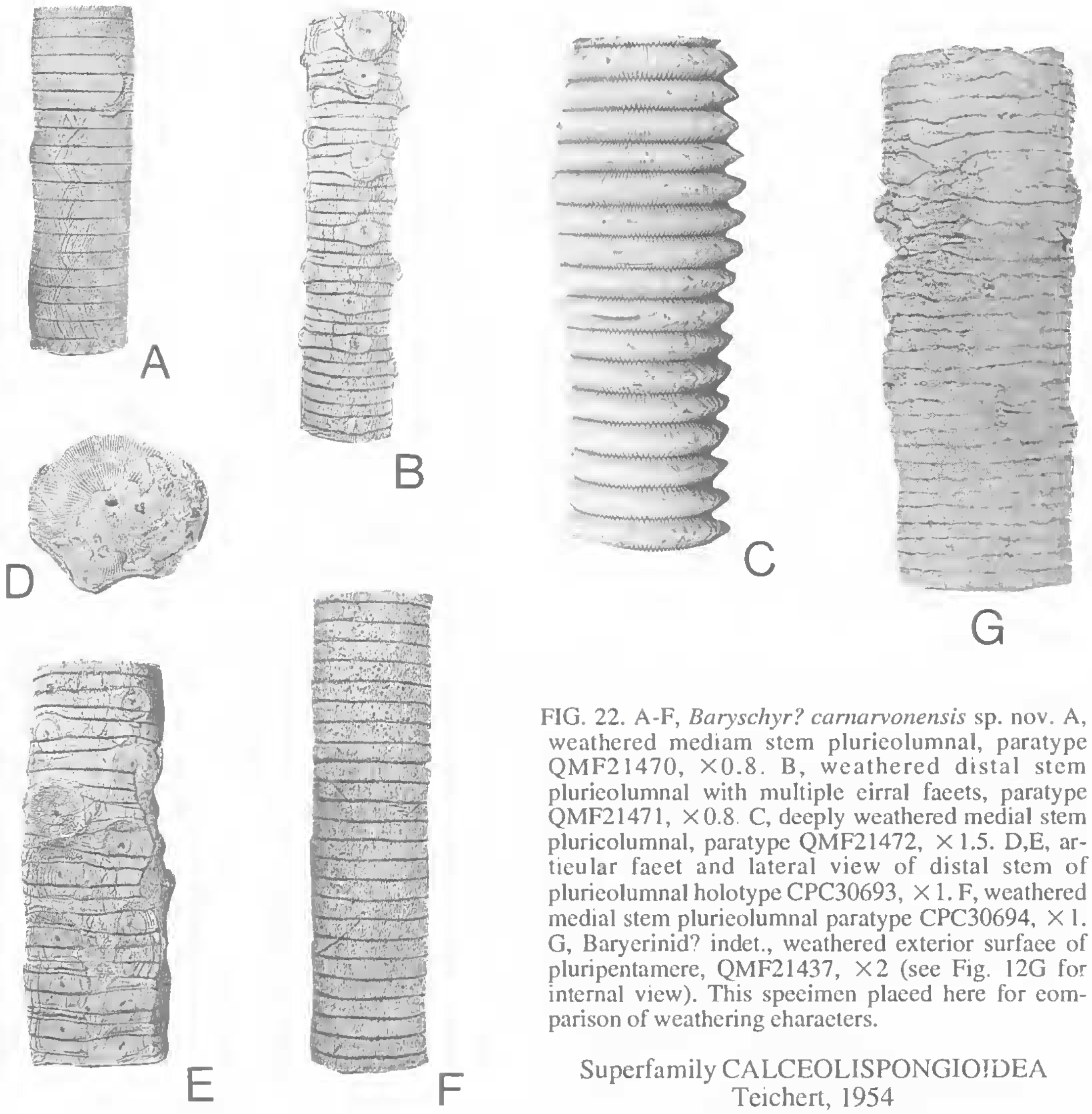


FIG. 22. A-F, *Baryschyr? carnarvonensis* sp. nov. A, weathered mediam stem pluricolumnal, paratype QMF21470, ×0.8. B, weathered distal stem pluricolumnal with multiple cirral facets, paratype QMF21471, ×0.8. C, deeply weathered medial stem pluricolumnal, paratype QMF21472, ×1.5. D,E, articular facet and lateral view of distal stem of pluricolumnal holotype CPC30693, ×1. F, weathered medial stem pluricolumnal paratype CPC30694, ×1. G, Barycrinid? indet., weathered exterior surface of pluripentamere, QMF21437, ×2 (see Fig. 12G for internal view). This specimen placed here for comparison of weathering characters.

and the weathered fracture is sometimes difficult to detect. Isolated spinose axillary brachials probably belonging to this specimen are moderately common at Callytharra Springs. Proximal series of brachials twice width (3.9 mm) of middle series (1.9mm); distal series (1.1 mm wide) >1/2 width of middle series. Except for spines on axils and smaller size, this set of arms is similar to *Notiocrinus timoricus* Wanner (1924a, pl.12, figs 18,19) from Basleo, Timor.

Because the branching pattern cannot be determined and the cup is lacking, the arms are questionably referred to Timorechinidae, with isotomous and heterotomous biendotomous arms.

Superfamily CALCEOLISPONGIOIDEA Teichert, 1954

Family CALCEOLISPONGIIDAE Teichert, 1954

Jimbacrinus Teichert, 1954

TYPE SPECIES

Jimbacrinus bostocki Teichert, 1954 from the Artinskian Cundlego Formation, Western Australia; by original designation.

Jimbacrinus donnellyensis sp. nov.
(Fig. 21)

ETYMOLOGY

For Donnelly's Well.

MATERIAL

Holotype CPC30685, paratypes CPC30686-30691 from the upper part of the Artinskian Bulgadoo Formation in the type section near Donnelly's Well.

DESCRIPTION

Crown small, pear-shaped, arms incurled distally. Cup bowl-shaped, walls subvertical, base slightly invaginated, moderately deep apical pits. IBB 5, kite-shaped, longer than wide, proximally downflared, distally upflared, visible in lateral view of cup. BB 5, hexagonal, subequal to wider than long, proximally subhorizontal, distally upflared becoming subvertical at distal tip; CD basal heptagonal, truncated distally for primanal. RR 5, pentagonal, wider than long, subvertical, bear shallow medial longitudinal depression. Radial facet plenary, bearing transverse ridge, outer ligament pit and marginal shelf. Primanal large, longer than wide, proximal 2/3 in radial circlet, adjoins 2 tegmen plates distally. Arms 5, atomous. Brachials rectilinear proximally, cuneate distally, strongly convex transversely, concave longitudinally, bearing faint longitudinal ridges after 3rd or 4th brachial; IBr_2 bearing two coarse slightly diverging laterally projecting blunt nodes. Pinnules large, elongate, one per brachial on alternate sides of arm. Stem pentagonal in section proximally; latus convex; heteromorphic type 1 pattern; distally round, homeomorphic, bearing few short cirri. Axial canal round.

MEASUREMENTS (mm)

	Holotype CPC30685	Paratype CPC30687	Paratype CPC30686
Crown height	16.7	11.5	
Crown width	12.5*	15.2*	
Cup height	4.1	4.3	
Cup width	6.1	-	
Diameter IBB			7.1
IBB length	1.9*	1.9*	3.4*
IBB width	1.8	1.7	3.1
BB length		2.5	2.2
BB width		3.1	2.2
RR length	2.3	2.0	
RR width	3.1	2.9	
Primanal length	1.8	1.7	
Primanal width	1.6	1.6	
Columnal diameter	1.4	1.4	1.6

*estimated

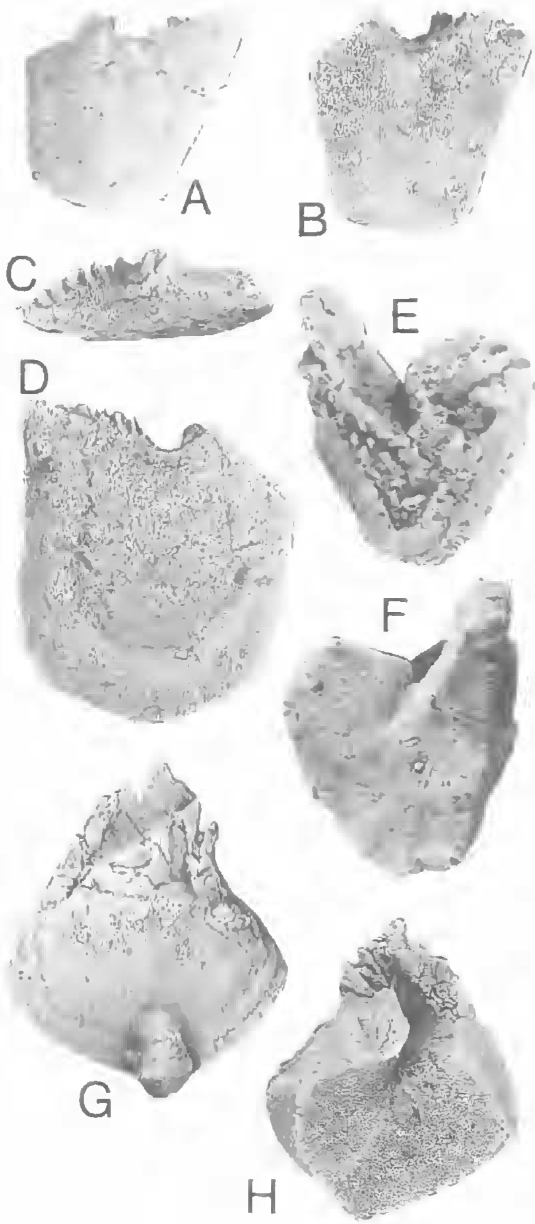


FIG. 23. *Neoschisma verrucosum* Wanner, 1924b. A,B, C radials QMF21481 and 21482, × 10 and × 6, respectively. C,D, oral and lateral views of D radial QMF21483, × 5 and × 6, respectively. E,F, external and internal views of epideltoid QMF21484, × 7. G,H, external and internal views of hypodeltoid QMF21485, × 4.

REMARKS

This description is a composite based on the 7 specimens. The holotype has a well preserved cup, proximal most column and C ray arm but exposed basals have been rounded by solution. One paratype (Fig. 21C) shows the infrabasal circlet and prominent protrusion on the basals. Two specimens (Fig. 21A,B) have well preserved brachials one and two, and two other specimens (Fig.21D) have well preserved columnals showing the gradation from the pentagonal to round sections within approximately one centimeter of the cup. Weathering has etched the surface of most specimens producing nodes and grooves which could be mistaken for ornamentation unless all specimens are considered.

Unlike most species of *Calceolospongia* that rested on the substrate with extended basals (Teichert, 1949), *Jimbacrinus* lived above the substrate supported by the stem (Teichert, 1954). All plates except the basals of *J. donnellyensis* are relatively thin and the crown is small relative to the stem; these features suggest an elevated life habit.

This is the third species of *Jimbacrinus* recognised and it is the oldest. It is easily distinguished from *J. bostocki* and *J. minilyaensis* by the wider basal plane and subhorizontally directed basal protuberances. *J. bostocki* probably evolved from *J. donnellyensis* by development of the central spine on the basals.

Family and genus indet.
(Fig. 18B)

MATERIAL

QMF21469 a partial set of arms from QML770.

REMARKS

This set of arms includes parts of 4 half(?) rays which could be a part or parts of one to three rays. The brachials are: moderately (proximally) to slightly (distally) wider than long; externally strongly convex transversely; bearing a medial longitudinal ridge terminating distally in a very short spine directed upward and outward; and moderately (proximally) to strongly (distally) cuneate. Brachials are slightly offset giving arms a slightly zigzag appearance, which is enhanced by the alternating direction of the medial ridge/spine. Isotomous endotomous or exotomous branching occurs twice on two of the partial rays and possibly a third time on one. A slender pinnule articulates with the branchial at the distal end of the medial ridge aboreal to the spine.

Classification of this specimen is uncertain. The zigzag brachials resemble some genera of the Decadocrinoidea, but they only have 10 arms, isotomously branching on the first or second primibrachial. Four superfamilies of the poteriocrininids include genera with endotomous or exotomous branching. The Hydreionocrinoidea have biserial arms and given no further consideration. The Pirasocrinoidea typically have spine rings capping the anal sac, brachials are rectilinear to faintly cuneate, and few genera are actually known to have endotomous or exotomous branching. *Linocrinus*, *Tholocrinus* and *Exocrinus*, of the Zeacrinitoidea have ray ridges or cuneate brachials but all lack the zigzag offset of the brachials. Only *Linocrinus*, has both ray ridges and cuneate brachials. Cuneate brachials are characteristic to several genera of the Texacrinoidea. *Galateacrinus ornatus* Moore, 1940 has medial ridges terminated in short spines on cuneate brachials, but the brachials are not offset.

Lacking proximal parts of the arms and the cup the specimen is left in open nomenclature. It is illustrated to show recognised diversity in the advanced poteriocrinid faunas from the Callytharra Formation. The branchials and branching pattern are sufficiently distinct to offer correlation potential if similar specimens are found elsewhere.

Family CYCLOMISCHIDAE Moore & Jeffords, 1968

Baryschyr Moore & Jeffords, 1968

Crinoid stem Foord, 1890, p.104, pl.4, fig.11.
Enlarged crinoid stem-portions Etheridge, 1903, p.25, pl.4, figs 1-9.

TYPE SPECIES

Baryschyr anosus Moore & Jeffords, 1968 from the Pumpkin Creek Limestone Member, Dornick Hills Formation, Pennsylvanian of Oklahoma; by original designation.

Baryschyr? carnarvonensis sp. nov.
(Fig. 22A-F)

ETMOLOGY

For the Carnarvon Basin.

MATERIAL

Holotype CPC30693, paratypes CPC30694, QMF21470, 21471, 21474 from QML770, QMF21472, 21473 from QML757 and 368 specimens as follows QMF21588 (11 specimens) from QML757, QMF21589 (25) from QML768, QMF21590 (11) from QML769, QMF21591 (201) from QML770, BMRF1643 (28),

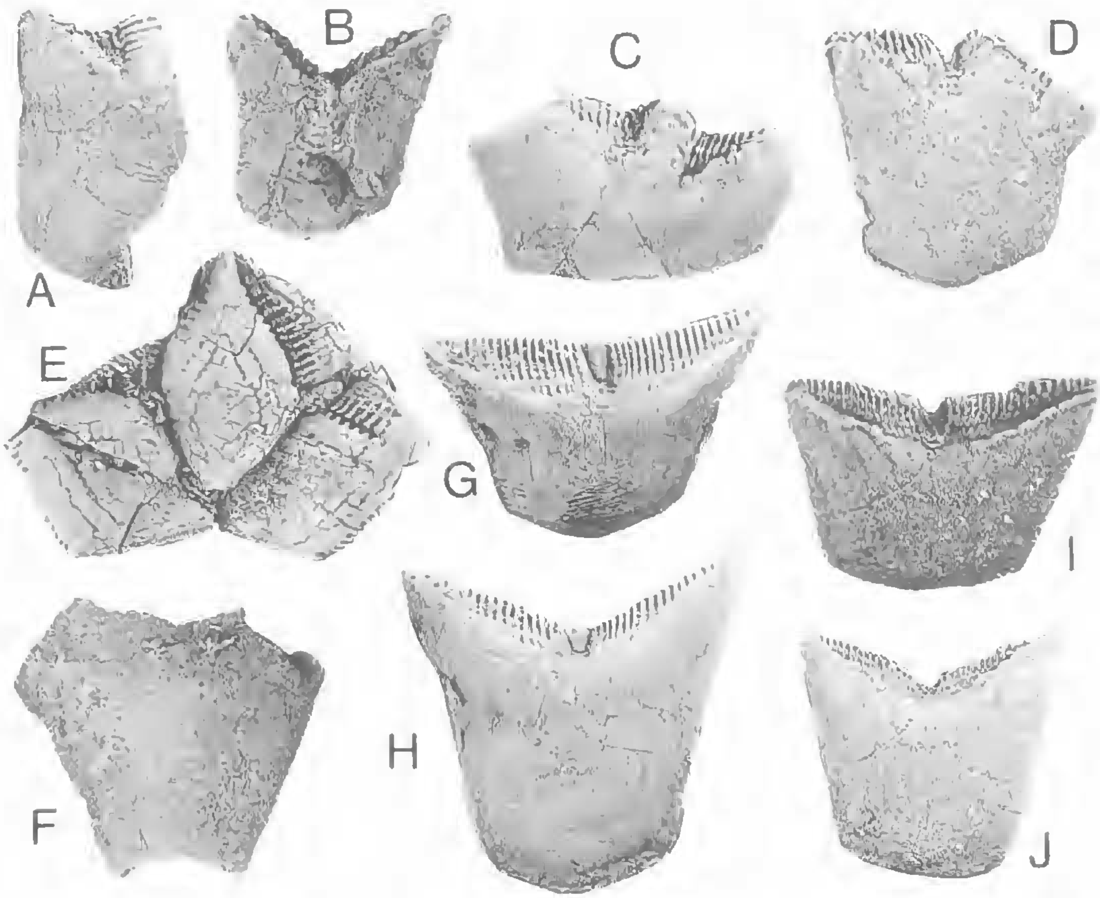


FIG. 24. *Neoschisma extensum* sp. nov. A, fragment of a C radial QMF21486, ×2. B, small radial QMF21487, ×5. C,D, a fragmentary and a complete D radial QMF21488 and 21489. ×3. E, fragmentary articulated theca NMVP127198, ×2.5. F, large basal plate QMF21490, ×2.5. G,H, oblique lateral and lateral views of large radial QMF21491, ×2. I,J, oblique lateral and lateral views of radial QMF21492, ×2.5 and ×2, respectively.

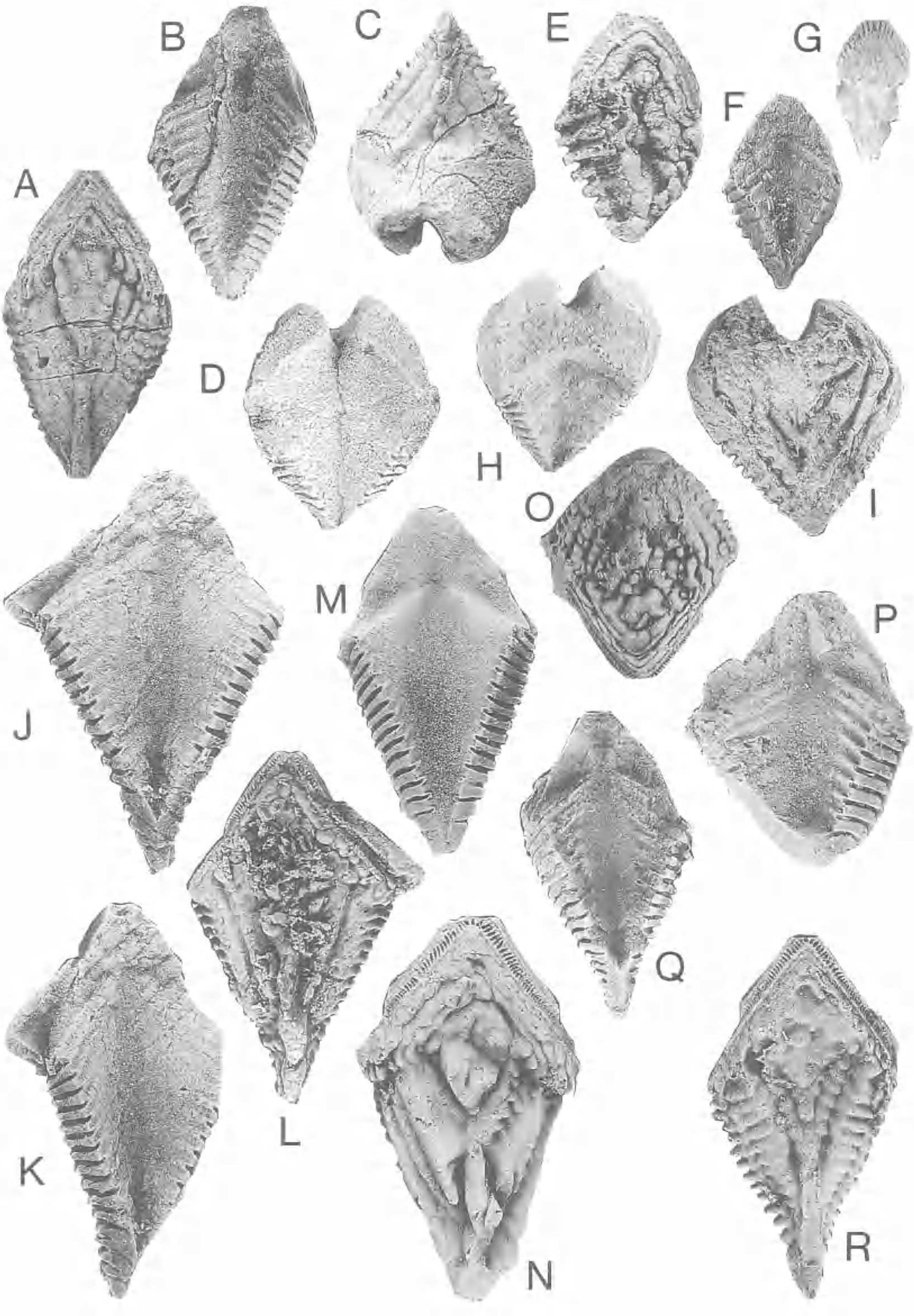
BMRF1644 (5), BMRF17226 (55), BMRF17601 (3), BMRF19385 (4), BMRF19386 (6), BMRCC139 (12), BMRG259 (3)and BMRGW84 (4).

Description

Proximal columnals unknown; medial columnals homeomorphic to heteromorphic type I; cirriferous distal columnals heteromorphic type I. Columnals circular in transverse section, axial canal pentagonal. Articulum wide, full facet width with no areola to nearly full facet width with narrow areola sloping into axial canal. Culmen fine, branching isotomously at midwidth to distal 1/4 of articulum, 40 per cm at mid width of articulum. Symplexy articulation. Latus smooth, straight. Axial canal narrows at moderately convex claustrum on each columnal. Cirri circular in transverse section, articulum like columnal articulum. Cirral scars aligned in part, may give columnal a rough pentagonal section, overlap 1 then 2 adjacent columnals as growth increases; cirri scars increase in size distally.

Remarks

Large pluricolumnals, 5.0-9.4cm long and 1.7-2.4cm diameter are especially common in exposures of the basal part of the Callytharra Formation throughout the Carnarvon Basin. They have been collected for many years and are present in most major museum collections throughout Australia. The first illustrations of these columnals was by Foord (1890) followed by Etheridge (1903) who reported infestations of endophytic fungus on some stem segments. More recently Welsh (1976) has demonstrated that these infestations and others referred to myzostomids by Warn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(1974), among others, are caused by *Phosphannulus*.

Considerable morphologic and diagenetic variation occurs in the pluricolumnals of *B.*? *carnarvonensis*. Many pluricolumnals lack cirri whereas others have a few and others many. Those with cirri show a progradation of increasing size of the facet distally and a corresponding alignment of the facet and more pentagonal transverse section of the columnals with the larger facet sizes. Heteromorphic noditaxial patterns change distally. Proximal patterns are 2 or 3 internodals between nodals in fairly regular repetitions. Distally internodals are fewer and occur infrequently, one every 3 to 7 nodals. The distal irregular noditaxis patterns correspond to the most cirriferous pluricolumnals.

Weathering of the pluricolumnals is greatest along articular facets resulting in pluricolumnals with a V-shaped or cog-shaped latus and what appears to be impressed sutures. Weathering on some specimens has been deep and results in irregularly shaped transverse cross-sections. The large axial canal collapsed under compaction after burial and many pluricolumnals appear elliptical in transverse section.

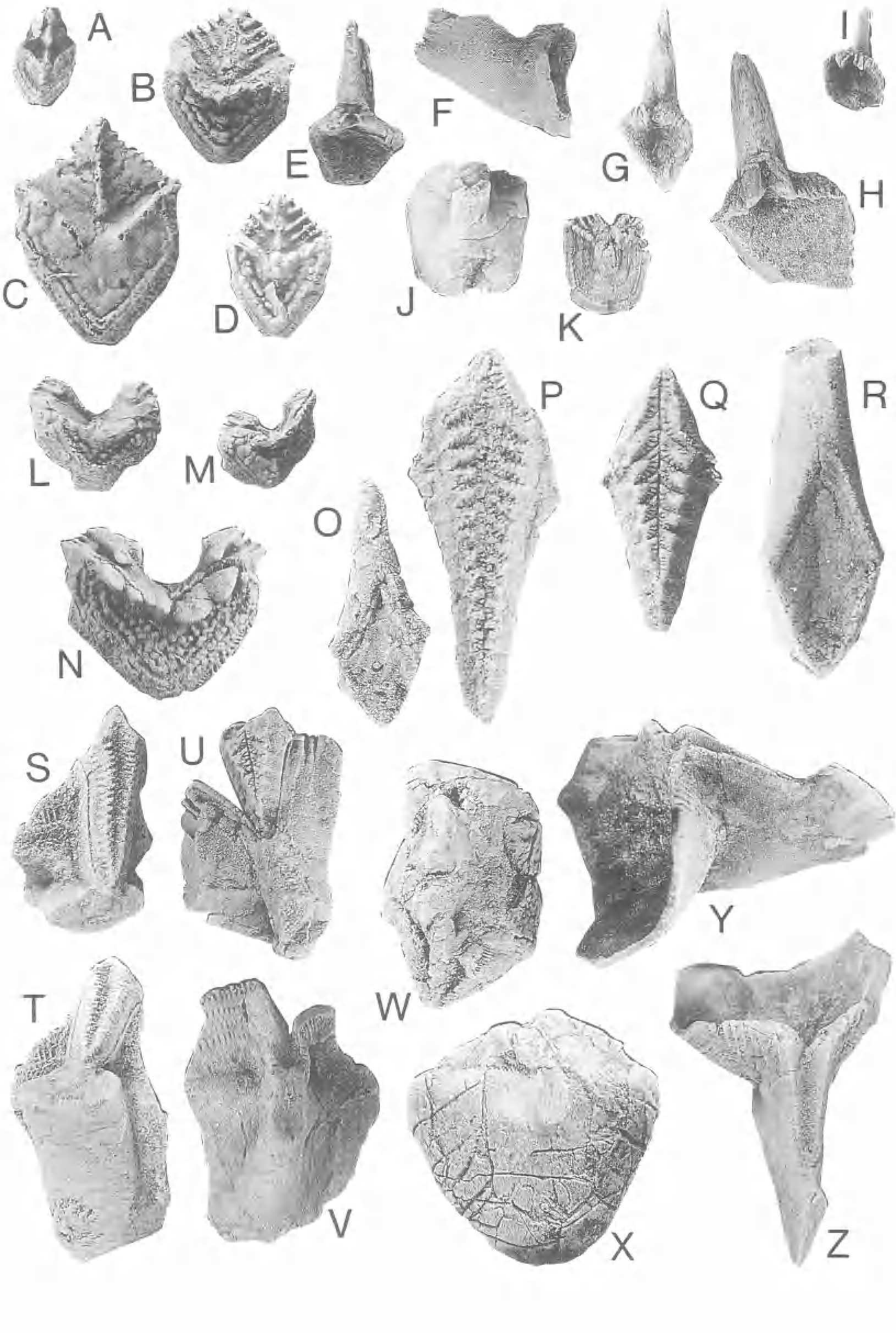
Class BLASTOIDEA

The only descriptions of Western Australian Permian blastoids have been those of Breimer & Macurda (1972) who named the fissiculates *Neoschisma australe* and *Notoblastus stellaris* and identified the Timorese species *Thaumatoblastus lonigramus* Wanner, 1924b in Western Australia and Breimer (1983) where the detailed species descriptions were provided. Apart from providing further information on each of these a new spiraculate species is described and the Timorese species *Neoschisma verruscosum* is recorded in W.A. Apart from this specific match all have generic links to Timor suggesting a close biogeographical link between the two areas.

Order FISSICULATA Jaekel, 1921
Family NEOSCHISMATIDAE Wanner, 1940

Breimer & Macurda (1972) discussed fissiculate phylogeny in great detail having established their classification apparently phenetically. All the fissiculates described herein are assigned to the Neoschismatidae following Breimer & Macurda. The only comment regarding intergeneric relationships concerns the placement of *Pterotoblastus*. Although placed in the Codasteridae by Wanner (1940) and by Breimer & Macurda (1972) *Pterotoblastus* appears to have quite a deal in common with various neoschismatids, in particular *Notoblastus*. The major distinguishing feature appears to be the reduction in the number of slits per hydrospire field and loss of slits on the anal deltoid in *Pterotoblastus*. Breimer & Macurda (1972) made an emphatic point that "Hydrospire structures of neoschismatids are essentially unchanged; ... There is no trend towards reduction in the number of hydrospire slits, neither in regular, nor in anal hydrospire groups". However, their further discussion of hydrospires in the Family reveals an abundance of slits in the earliest representative, *Hadroblastus*, and several of the Permian genera but in several species, effective reductions are recorded. According to Breimer & Macurada (1972, p. 346) these reductions are effected through filling of the slits by secondary calcite deposits. They regard *Timoroblastus* as a form with most of its slits completely closed off by secondary calcite. *Pterotoblastus* has more slits than *Timoroblastus* and the small number in each genus could be due to the same process, calcite infilling of most slits. In the anal interray groups of slits, *Neoschisma* contains one species with approximately the same number of slits as non-anal groups because the hypodeltoid bears numerous slits; a second species has a greatly reduced number where the hypodeltoid does not bear slits. In *Notoblastus* there are 1-5 slits in each anal hydrospire field. This is significantly fewer than in anal fields of certain species in other genera where slits are present on both epi- and hypodeltoids. Even in *Notoblastus*, *N. cornutus* (McKellar, 1969) has 5 slits per group in the D interray, *N. oyensi* (Wanner, 1940) and *N. stellaris* have 3 and *N. brevispinus* has 2. Therefore, we consider that the difference between 2 and 0 slits in the anal group no more significant than that between 5 and 3. We suggest that *Pterotoblastus*

FIG. 25. *Neoschisma extensum* sp. nov. A,B, external and internal views of deltoid QMF21493, ×4. C,D, external and internal views of holotype hypodeltoid QMF21494, ×4. E,F, external and internal views of small deltoid QMF21495, ×7 and ×6, respectively. G, external view of small deltoid QMF21496, ×6. H,I, internal and external views of hypodeltoid QMF21497, ×4, J-L, internal, internal oblique and external views of large deltoid with lancet still attached QMF21498, ×4. M,N, internal and external views of large deltoid QMF21499, ×4. O,P, external and internal views of deltoid QMF21500, ×4 and ×5. Q,R, internal and external views of deltoid QMF21501, ×4.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may be more correctly classified with the essentially Permian Southern Hemisphere group, the Neoschismatidae.

Neoschisma Wanner, 1924b

TYPE SPECIES

N. verrucosum Wanner, 1924b from the Permian of Timor; by original designation.

Neoschisma verrucosum Wanner, 1924b (Fig. 23)

Neoschisma verrucosum Wanner, 1924b:7, pl. 199, figs 9,10.

Neoschisma verrucosum Wanner; Breimer & Macurda, 1972:31, pl.19, fig.5; pl.20, fig.7.

Neoschisma australe Breimer & Macurda, 1972:31, pl.19, figs 6,7. [non figs 1-4, 8].

Neoschisma verrucosum Wanner;Breimer, 1983: 126, pl.26, figs 5,7,9.

Neoschisma australe Breimer & Macurda; Macurda, 1983: pl.27, fig. 2 (only); pl.28, figs 7-9, 12.

MATERIAL

Western Australia – UMMP58682 (holotype of *N. australe*) from the type section of the Callytharra Formation, 0.88 km west of Callytharra Springs, WA. QMF21485 an hypodeltoid, QMF21484 an epideltoid and QMF21481-21483 radials from QML757.

DISCUSSION

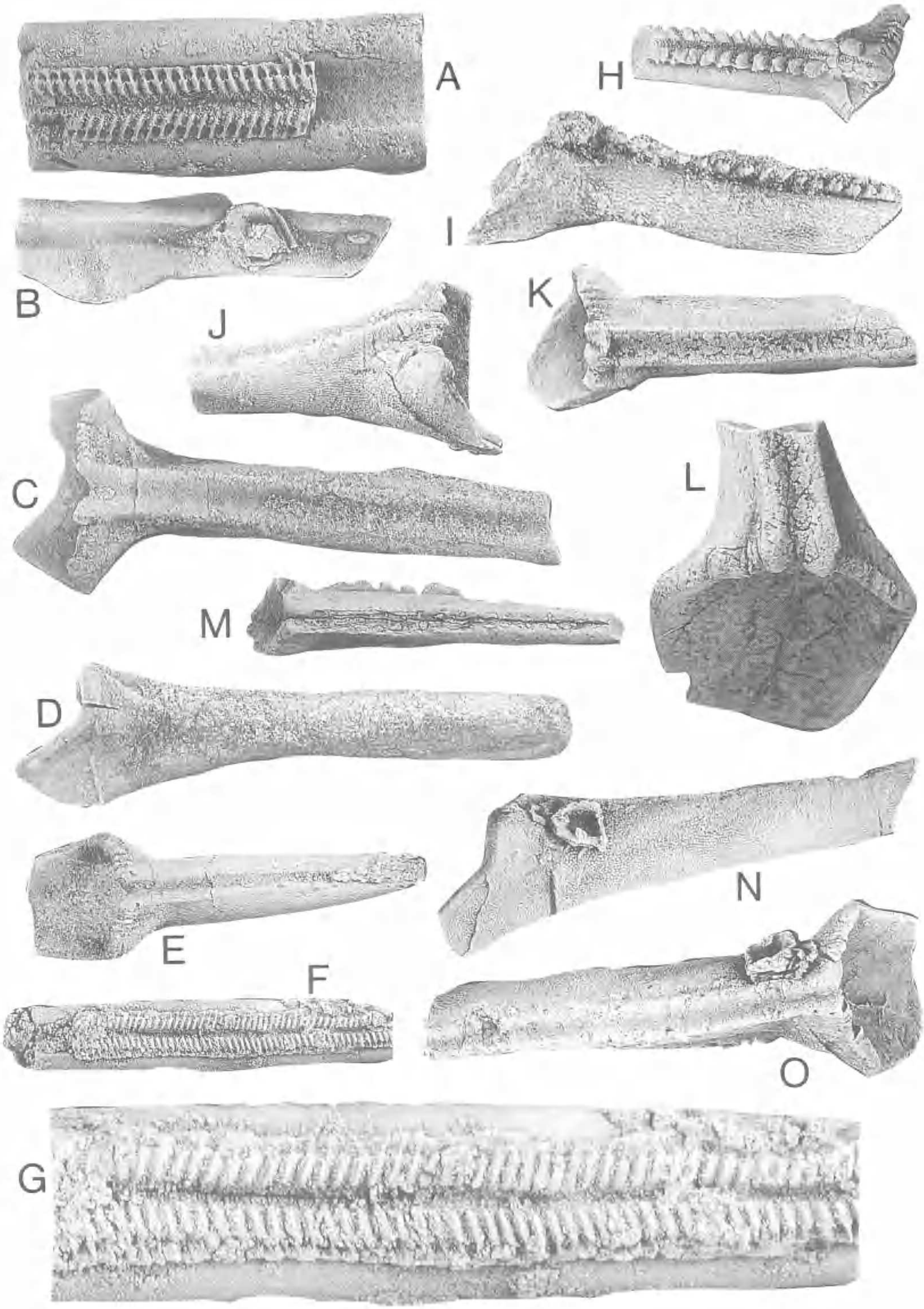
Breimer & Macurda (1972) diagnosed *N. australe* as having a flat rather than scalloped vault and as having hydrospire slits developed on both the epi- and hypodeltoids. The surface of the vault was a variable feature in the Callytharra collections with the depth of the V in the top of the radials and the convexity of the deltoids varying with growth and among individuals of similar size. With the relatively few specimens available this feature would seem unsuitable for species separation. However, development of hydrospire slits on both epi- and hypodeltoids should be clear cut. In the type species, the hypodeltoid does not bear any hydrospire slits (Wanner, 1924b, pl. 199, fig. 10; Breimer & Macurda, 1972, pl. 19, fig. 5). In the holotype of *N. australe* (Breimer & Macurda, 1972, pl. 19, figs 6, 7) the hypodeltoid is a flat, fairly upright plate, tapering adorally but not pointed, with the anal aperture an indistinct invagination into the adoral side and with a distinct double tubercle medially on the aboral RD margin.

Another such plate (Fig.23G,H) is now available with the same shape, distinctive aboral tubercle and ragged adoral margin. In this specimen the protruding ragged adoral edge conceals the anal aperture which is obvious on the internal side. The anal opening cuts through a prominent curving ridge that runs across the plate. A low but distinct ridge runs from near the centre of this gap to the RD margin towards the C side. Moreover this specimen bears no hydrospire slits. On this basis we assign the holotype of *N. australe* and the isolated hypodeltoid mentioned above to *N. verrucosum* based on the lack of hydrospire slits on the hypodeltoid. Radials (2 C and 1 D radials; Fig.23A-D) with truncated upper corners are referable to this species also; the truncation corresponds to the RD margin along the hypodeltoid.

On the other hand, the hypodeltoid figured by Breimer & Macurda (1972, pl. 19, fig. 1) and two others (Fig. 25C,D,H,I) do bear numerous hydrospire slits. These plates represent a separate species and are described below. To that species are also assigned several radials which may be identified as having the "broad convex humped area" described by Breimer & Macurda (1972, p.32) in the hydrospire field adjacent to the hypodeltoid near its widest point. However, many radials, basals and deltoids, from other than the anal part of the theca are not able to be assigned with certainty. They are here assigned to *N. extensum* for convenience only.

The epideltoid (Fig.23E,F) is assigned to this species because the anal opening is irregular, anal collar very low and there are hydrospire slits on both its aboral extremities. Despite the considerable size difference between this epideltoid and available hypodeltoids it seems to fit with the hypodeltoid described above in that the low collar

FIG. 26. *Notoblastus stellaris* Breimer and Macurda, 1972. A-D, external views of deltoids QMF21502-21505. A,B, ×7; C,D ×6. E, oral view of small radial QMF21506, ×4. F,G, lateral and oral views of small radial QMF21507, ×4. H,I, oral views of radials CPC30967 and QMF21508, ×3 and ×5, respectively. J,K, lateral views of small radials QMF21509 and 21510, ×4. L-N, oral view of epideltoids QMF21511-21513. L,M ×5; N ×7. O,P, internal and external views of lancet QMF21514, ×7 and ×10. Q, external view of lancet QMF21515, ×10. R, internal view of lancet QMF21516, ×9. S,T, oral and lateral oblique views of fragment of a radial with lancet still in place CPC30695, ×4. U, fragmentary radial and lancet QMF21517, ×6. V, fragmentary radial CPC30966, ×3. W,X, oral and lateral views of articulated but badly weathered theca NMVP127199, ×2.5. Y,Z, lateral and oral views of large radial QMF21518, ×3.5.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and irregular opening would fit better with the overhanging anal opening described above.

Neoschisma extensum sp. nov.
(Figs 24,25)

Neoschisma australe Breimer & Macurda, 1972:31, pl.19, figs 1-4, 8.
Neoschisma australe Breimer & Macurda; Breimer, 1983:122, pl.27, figs 1, 3-12; pl.28, figs 1-6, ?10, 11, 13-16; pl.30, fig.3.

ETYMOLOGY

Latin *extensus*, stretched out; referring to the anal collar.

MATERIAL

Holotype QMF21494, an hypodeltoid from QML760. Paratypes hypodeltoid and D radial (Breimer & Macurda, 1972, pl. 19, fig. 1), C radial (Breimer & Macurda, 1972, p. 19, fig. 3, 4; BMR GW137), D radial (Breimer & Macruda, 1972, pl. 19, fig. 8) NMVP127198 an articulated but crushed and incomplete theca from 20.3m in the type section of the Callytharra Formation, 0.88km west of Callytharra Springs. QMF21490 fragmentary basal, QMF21486-21489, 21491, 21492 almost complete radials, QMF21493, 21495, 21498-21501 deltoids, hypodeltoid QMF21497 from QML757. One deltoid, QMF21496 from QML760.

DISCUSSION

The problem of assigning non-anal plates to *N. verrucosum* or this new species has been discussed above as has the hypodeltoid with hydrospire slits belonging to the new species. One hypodeltoid (Fig.25C,D) is of the same maximum width as the isolated hypodeltoid of *N. verrucosum* (Fig.23G,H) so the different hypodeltoids may not be attributed to different growth stages of the same species. Any isolated plates of *Neoschisma* that cannot be definitely referred to one or other of the species is tentatively referred to this new species.

The description of *N. australe* as given by Breimer & Macurda (1972, p. 32) and Macurda (1983, p.122) should be applied to this new species except as varied in the following. The fragmentary basals suggest that the BB sides of the plates diverged strongly adorally to give the theca a strongly flared base. In large radials, lateral edges are not always straight; often having a gently sigmoidal curve over adoral half (Fig.24H). In C and D radials hydrospire slits are absent in a zone near to and on the anal interarea side of the central and ambulacral notch. This zone was described by Breimer & Macurda (1972) as that where a "broad convex humped area formed". In specimens available to us (Fig.24A,C,D) the convexity is at right angles to the hydrospire slits and parallel to the RD margin with sharp furrows crossing the humped area also parallel to RD margin (Breimer & Macurda, 1972, pl.19, fig.4; Fig.24A). The upper margin of this convex zone is in contact with a convex face on the hypodeltoid just adoral to the hydrospire slits. On the interior side of this convex area on the radial is a shallow concave channel that leads across the RD suture along the deltoid to the anal opening. Lateral to this convex zone on the radial, the projection of the radial limb is greatly reduced and in one specimen the hydrospire field is declined aborally (Fig.24D). In this same CD interarea position there appears to be a greater than normal development of secondary calcite in front of the slits and one specimen (Fig.24D) a shield has grown almost completely hiding the slits from lateral view.

One available deltoid (Fig.25O,P) is much shorter, in interradial direction, than other deltoids. This specimen has the aboral tip slightly downturned forming a shallow aboral pocket on the internal surface. It has 8 hydrospire slits on one

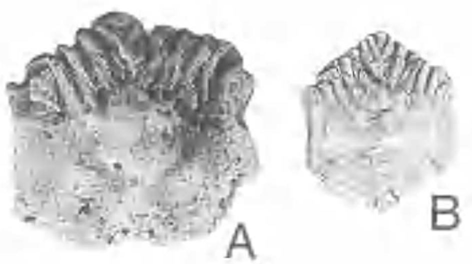
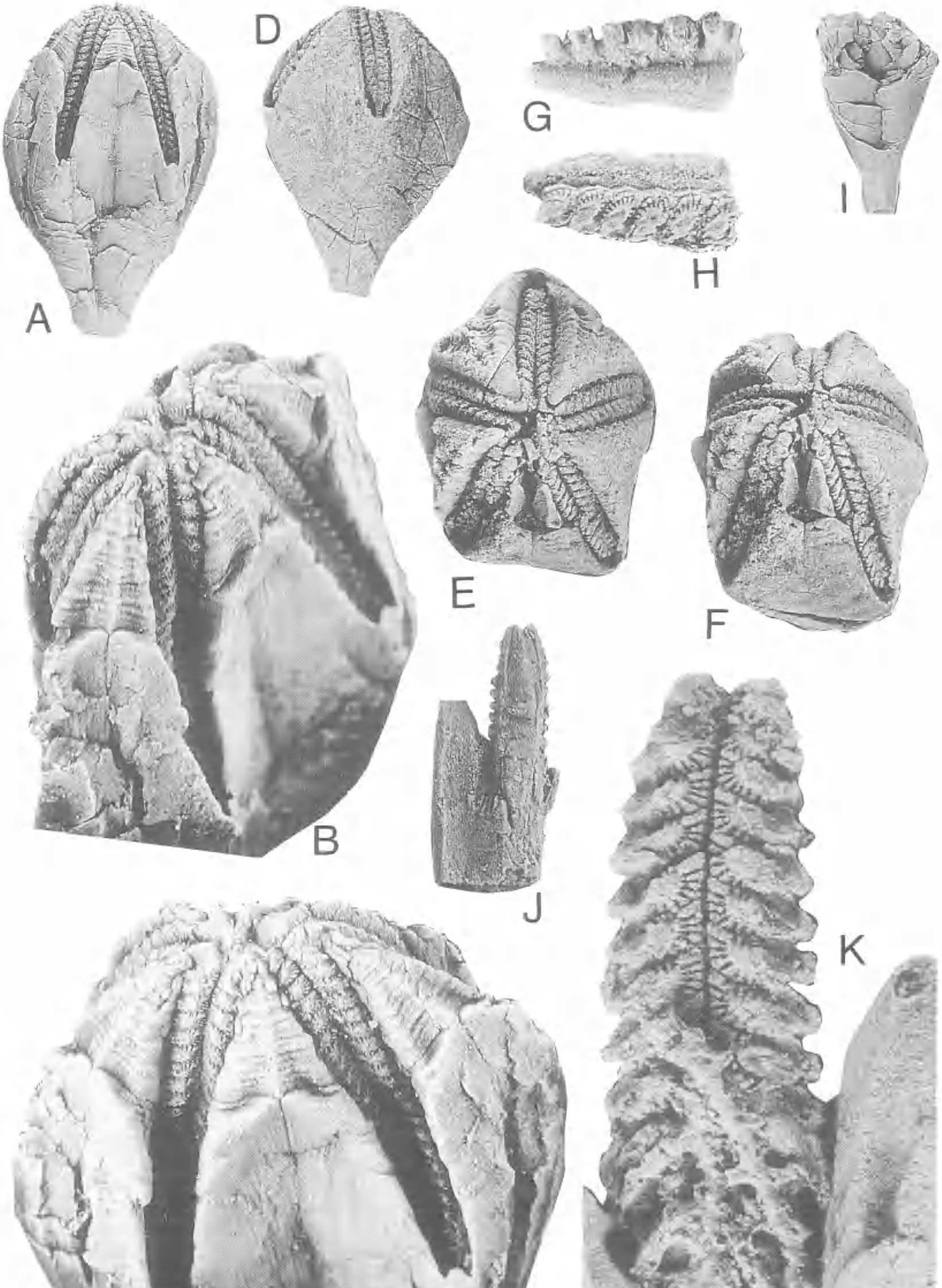


FIG. 28. Deltoid indet. A, CPC30710, x4. B, QMF21553, x3.

FIG. 27. A,F,G, *Thaumatoblastus* sp. nov. fragments of radial projection from KNF73. A, CPC30698, ×3. F,G, CPC30702, ×3 and ×7.5, respectively. B-E, J-O, *Thaumatoblastus* indet. B-E from KNF73; J-O from ML89. B, fragment of radial projection showing branched ambulacral tract, CPC30699, ×3. C,D, oral and lateral views of radial with incomplete projection, CPC30700, ×3.5. E, radial, CPC30701, ×4. J-M, radials with incomplete projections, CPC30705, 30706, 30707, 30708, respectively, ×2.5, ×3, ×3, ×4, respectively. N,O, lateral and oral views of radial with incomplete projection and upon which a juvenile mollusc shell (probably an oyster) has attached, CPC30709, ×2.5. H,I, *Thaumatoblastus longiramus* Wanner, 1924b, radials with incomplete projections but retaining the lancet and side plates, CPC30703, ×4 and CPC30704, ×3.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side and only 3 or 4 on the other, whereas elongate deltoids of comparable width may have 15 or 16 slits. The side with only 3 or 4 slits has a long aboral zone without slits. Whether this is from an aberrant specimen or there is some other explanation is not known at present. We have no epideltoid to assign to this species. The two hypodeltoids appear dissimilar principally because one has a very high anal collar, subdued comarginal ornament and prominent distal blade-like projection whereas the other has no raised anal collar, prominent sharp comarginal ridges and no distal projection. On the latter specimen the anal collar and distal projection may have bene removed by postmortem abrasion. Internally (Fig.25D,H) the two plates are identical with a ridge across the plate at the adoral end of the hydrospire slits. On the surface of the anal groove, adoral to the transverse ridge, are low irregularly placed tubercles. Adorally on the plate are a pair of flat facets presumably for junction with the epideltoid.

One deltoid retains a lancet on one side (Fig.25J-L) and one radial retains the short aboral tip of the lancet in the ambulacral notch (Fig.24G,H). The DD margin of the deltoid is straight adorally, then slightly concave and convex dipping down aborally. This shape is well illustrated in the assembly of Breimer & Macurda (1972, pl.19, fig.1) but the dorsal half of deltoids should be in contact. In oral view the lancet corresponds to this shape being narrow and depressed adorally beneath the abutting deltoids, but wider and flush, with the sides of the deltoids in the main body area where deltoids do not touch. In Breimer & Macurda's (1972, p.33) description it is not clear which part of the lancet is being referred to as adoral and which is aboral; in this work the adoral section is where the ambulacral groove is supported entirely by the deltoids, the main body is where the ambulacral groove is supported by the lancet and adoral section is on the radial. The lancet is widest at aboral end of main body, tapering very slowly adorally it disappears internally at adoral end of the main body. Small transverse grooves are evident within the ambulacral tract but the arrangement of side plates or even their presence is not confirmed by available material.

Notoblatus Brown, 1942

TYPE SPECIES

Notoblastus brevispinus Brown, 1942 from the Early Permian of New South Wales; by original designation.

Notoblastus stellaris Breimer &Macurda, 1972 (Fig. 26)

Notoblastus stellaris Breimer & Macurda, 1972:34, pl.20, fig. 1; pl.21, figs 1,2,7,8.

Notoblastus stellaris Breimer & Macurda; Breimer, 1983:132, pl.29, figs 5-7,11,12; pl.30, figs 1,2,4-10,15-17.

MATERIAL

Holotype UMMP58683 from the type section of the Callytharra Limestone on the Wooramel River, WA. NMVP127199 an articulated but weathered specimen from locality BB929 which is 20.2m above the base of Section 7 on Mt. Sandiman Station, 1.9km at 15° from Mt Sandiman Woolshed, from the collection of Dr G.A. Thomas, now housed in the Museum of Victoria. Radials QMF21506-21510, 21517, 21518, CPC30965, 30967, deltoids QMF21502-21505, epideltoids QMF21511-21513, and lancets QMF21514-21516 from QML757.

DISCUSSION

This species was described in detail by Breimer and Macurda (1972:34) and Macurda (1983:132); only where new information is available are comments added here. However, an attempt is made to illustrate several features and plates not obvious in earlier papers.

The theca described here is taller than that of Breimer & Macurda (1972) with the basals accounting for some 25-30% of total height; the height is 17mm and maximum width 16mm but this theca is compressed laterally so the width is overstated. In life the theca must have been considerably higher than wide.

On the radials, the ambulacral sinus extends along the radial projection to the point where the projection turns upwards; in the smaller specimens this means the sinus does not extend onto the projection at all but in the largest radial (Fig.26Y,Z) the sinus extends well out onto the projection to the point where the upper surface of the projection is about to turn upwards. There

FIG. 29. *Rhopaloblastus cuspidus* sp. nov. A-C, lateral, oral oblique and lateral oblique views of holotype theca QMF21519, A ×3; B,C ×7. D-F, lateral, oral and posterior oblique views of paratype theca NMVP94182. D ×3; E,F ×4.5. G,H, lateral and oral views of fragment of a lancet with 6 side plates attached QMF21520, ×10. I, basal circlet of small theca QMF21521, ×3. J,K, internal and external views of a lancet still in place on a radial QMF21522, ×4 and ×15.

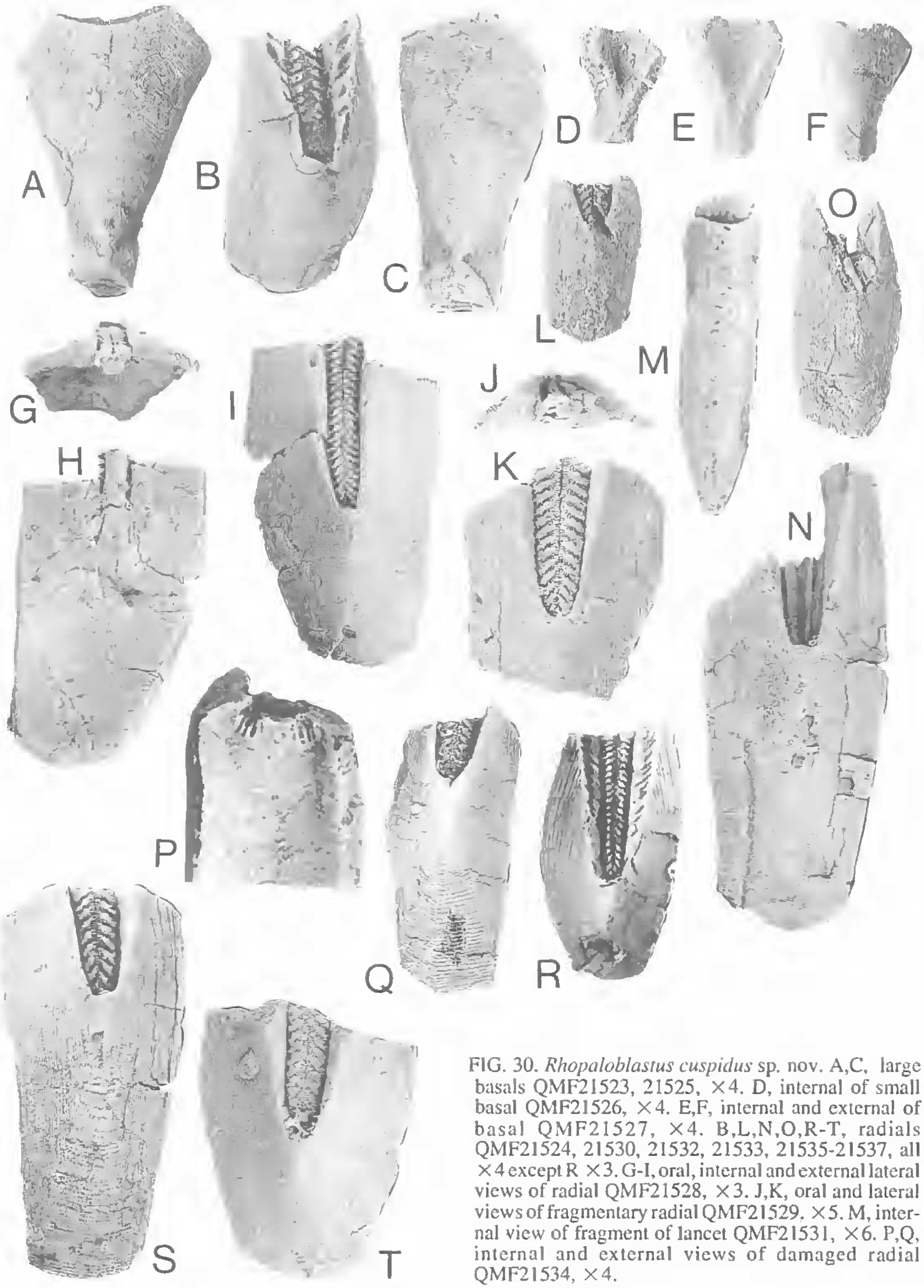


FIG. 30. *Rhopaloblastus cuspidus* sp. nov. A,C, large basals QMF21523, 21525, ×4. *D*, internal of small basal QMF21526, ×4. E,F, internal and external of basal QMF21527, ×4. B,L,N,O,R-T, radials QMF21524, 21530, 21532, 21533, 21535-21537, all ×4 except R ×3. G-I, oral, internal and external lateral views of radial QMF21528, ×3. J,K, oral and lateral views of fragmentary radial QMF21529, ×5. M, internal view of fragment of lancet QMF21531, ×6. P,Q, internal and external views of damaged radial QMF21534, ×4.

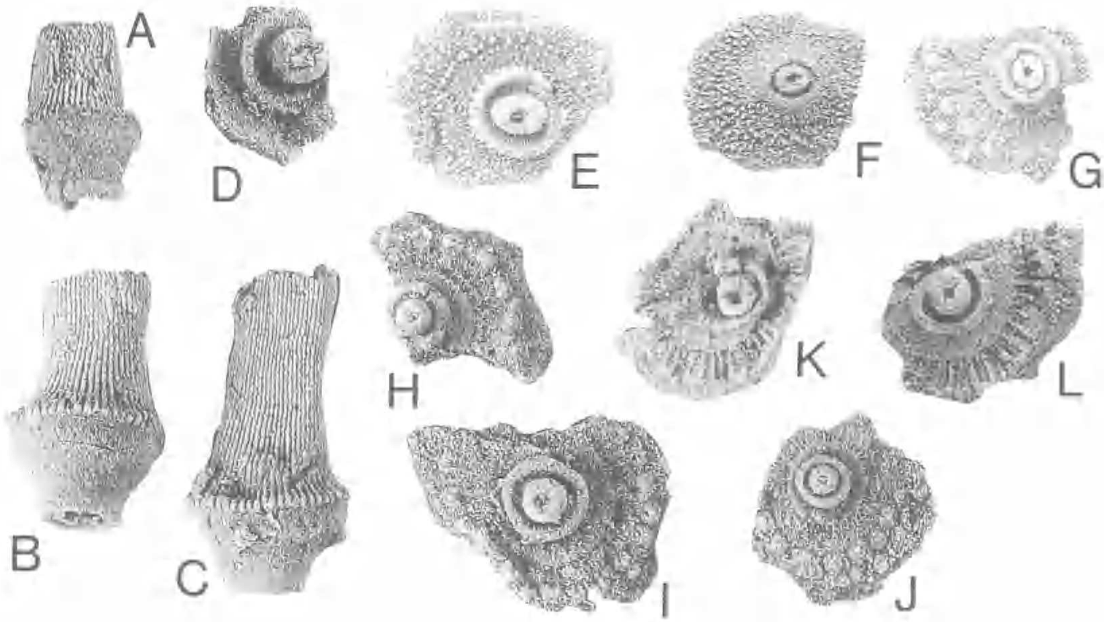


FIG. 31. Cidaroid indet. A-C, spine bases QMF21541-21543, ×4. D-L, fragmentary interambulacrals QMF21544-21550, all ×7 except E and I ×6.

appears to be some variation in the shape of radials through growth but the small sample size and degree of postmortem deformation make it impossible to identify how much. In the CD interray, hydrospire slits are reduced to one or two per field and these situated close to the ambulacrum. In the smaller radials described here, both in the articulated specimen and as disassociated plates, the hydrospire fields are not evident in lateral view; although the individual plates all appear to have undergone a degree of distortion this is unlikely to have accounted for the attitude of the hydrospire fields in every case. In large radials (Fig.26S,U,Y,Z) the hydrospire fields are more upright and evident in lateral view.

Epideltoid same as a deltoid except that hydrospire fields are reduced to 1 or 2 slits on each margin projection at lateral extremes; these projections were sutured to radials. On inner sides of these projections are elongate facets that presumably sutured to the hypodeltoid. In the centre of the plate was a large circular anal opening. The adorally chevron-shaped ridge of the deltoid is greatly accentuated. No plate in our collections may be certainly identified as the hypodeltoid but its shape is inferred from the epideltoid and radial that would have bounded it. The hypodeltoid must have been wide and rhomboidal with the adoral corner excavated by the anal opening so that a shape approaching broadly arcuate is possible.

Since isolated lancets and those still in the ambulacra of weathered radials (Fig.26S,U) show the lancet to be elongate rhomboidal in plan view. The adoral part (i.e. from widest point to adoral tip) is shorter than aboral part which tapers very gently and extends to tip of ambulacrum. Laterally on adoral part are the slightly protruding faces that abut the excavation into the sides of the deltoids. On internal surface is an adoral diamond shaped area bounded by a distinct ridge and with concave surface. The aboral tip of the diamond fills the V-shaped gap in the radial and the aboral extension with rounded inner surface lies in the ambulacral groove on the radial.

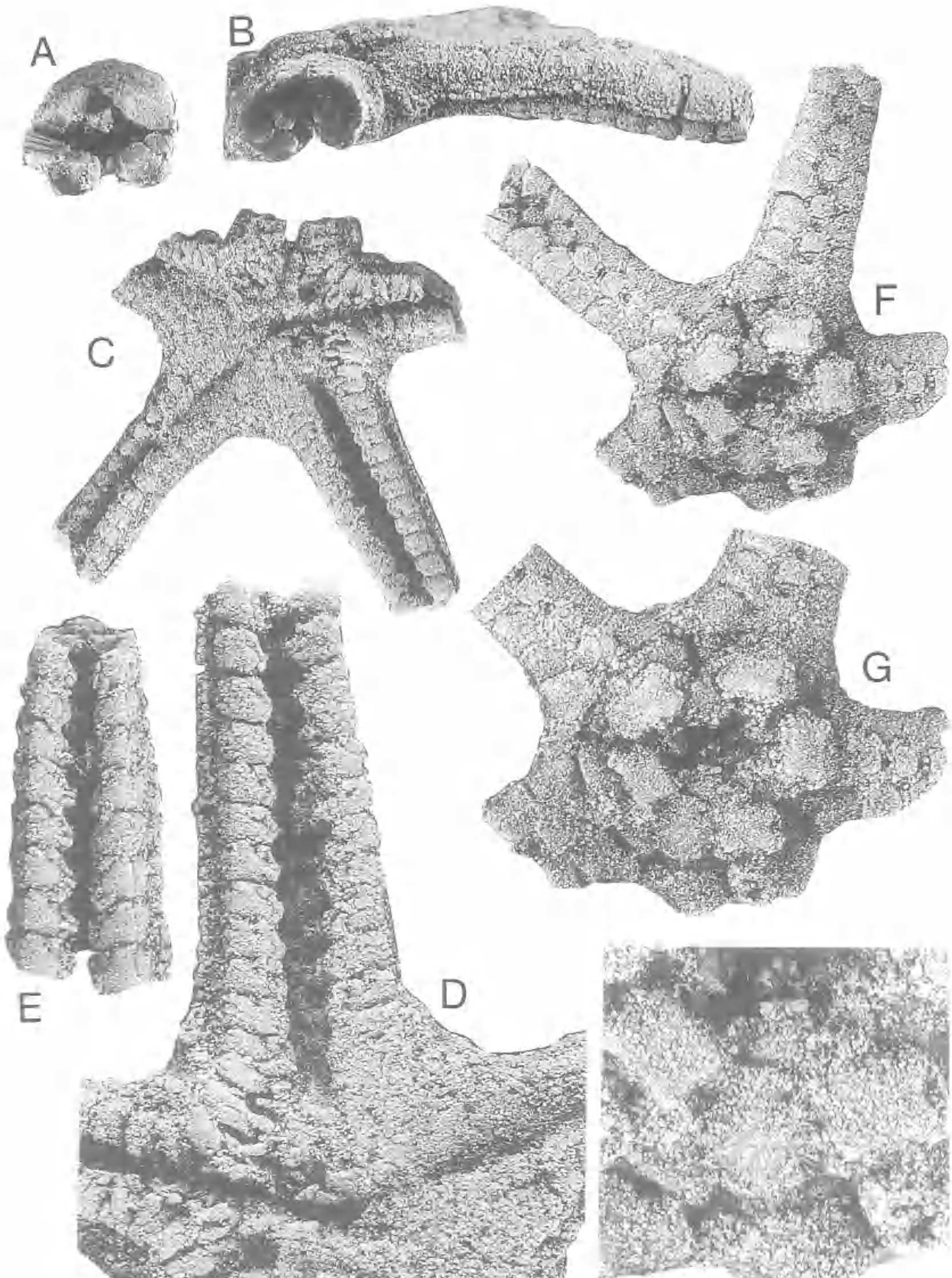
Thaumatoblastus Wanner, 1924b

TYPE SPECIES

Thaumatoblastus longiramus Wanner, 1924b from the Permian of Timor; by original designation.

Thaumatoblastus longiramus Wanner, 1924b (Fig.30H,I)

Thaumatoblastus longiramus Wanner: Breimer & Macurda, 1972:36, pl.24, fig.2; pl.25, figs 1-8; pl.28, fig.5.


A
B
C
D
E
F
G
H

Thaumatoblastus longiramus Wanner: Macurda, 1983:135, pl. 31, figs 7-10; pl.32, figs 1-10.

MATERIAL
Radial plates CPC30703, 30704 from ML87.

REMARKS
One of these radials (Fig.27H) was figured by Breimer & Macurda (1972, pl.25, fig.5) and agrees with the other in size of the side plates relative to the width of the ambulacrum. These side plates appear to be the same size and shape as figured by Wanner (1924b) and their assignment to the type species is accepted.

Thaumatoblastus sp. nov.
(Fig.27A,G)

MATERIAL
Radial plates CPC30698,30702 from KNF73 and QMF30705-30709 from ML89.

REMARKS
The two specimens with lancet and side plates preserved (Fig.27A,F,G) show a greater number of side plates per centimetre of ambulacrum when compared with the 2 radials described above as *Thaumatoblastus longiramus*. These two specimens are considered specifically separate but because they are so incomplete no new specific name is introduced.

Thaumatoblastus sp. indet.
(Fig.27B-F,J-O)

MATERIAL
Radial plates CPC30699-30701 from KNF73 and QMF30705-30709 from ML89.

REMARKS
Assignment of these radials, that have lost their lancet and side plates, to either of the species mentioned above is not possible with the present state of knowledge. However, it is likely that they belong to one or other of the species occurring in Western Australia. All those radials figured by Breimer & Macurda (1972, pl.24, fig.2; pl.25, figs 1-4, 6,8; pl.28, fig.5) which do not retain a lancet or side plates are in the same situation and definite specific assignment will depend on more detailed study of this and better material from Western Australia and Timor if and when it becomes available.

Family UNCERTAIN
Deltoid indet
(Fig. 28)

MATERIAL
Two plates QMF21553 from QML757 and CPC30710 from 20m above base of the type section of the Callytharra Formation.

DESCRIPTION
These two plates are hexagonal with the six sides virtually of equal length. Two adjacent sides have 7 or 8 slits normal to the margin; interpreted as hydrospire slits. Comarginal growth lines are evident parallel to the other sides; a group of 6-9 low rounded tubercles are situated centrally with the central tubercle highest and most prominent.

REMARKS
Although these plates are abraded and only one is preserved so as to be confident of its features they are interpreted as the deltoid plates of some blastoid because of the hydrospire slits and general resemblance to the deltoids of *Notoblastus* described above. However, the six even sides to these plates and apparently unspecialised edges (ie. other than those with slits) are features unknown among the blastoids. Their identity even as blastoid plates, remains a mystery at present but they are recorded to show the diversity.

Order SPIRACULATA Jaekel, 1921
Family PENTREMITIDAE d'Orbigny, 1851

Rhopaloblastus Wanner, 1924b

TYPE SPECIES
R. timoricus Wanner, 1924b from the Permian of Timor; by orginal designation.

DIAGNOSIS
See Breimer & Macurda, 1965:216.

REMARKS
Breimer & Macurda (1965) considered *Rhopaloblastus* to differ from other genera in the Pentremitidae by its petaloid ambulacra and exposed cryptodeltoids. The species described below has exposed cryptodeltoids but ambulacra,

FIG. 32. *Monaster coleyi* sp. nov. A,E, adoral end and oral view of arm fragment (could be part of holotype but not certain) NMVP127201, ×7 and ×8, respectively. B-D, F-H, holotype NMVP127200. B, lateral view of A ray, ×5. C,D, oral view, ×4 and ×7. F,E, aboral view, ×4 and ×6. G, enlargement of madreporite area, ×10.

in the largest available specimen, are not petaloid but rather elongate, much more in the style of *Calycoblastus*. We have assigned the species with the emphasis on the anal deltoid arrangement because that feature seems generically more consistent through the blastoids. The smaller theca (Fig.29D,E) exhibits more petaloid ambulacra but in all other respects this species coincides better with the type of *Calycoblastus* than *Rhopaloblastus*. *Calycoblastus* was originally protrayed (Wanner,1924b) as having eight spiracles and an anispiracle. Brown (1942) credited *C. casei* from New South Wales with 10 spiracles. However, Breimer & Macurda (1965) re-examined the holotype of the type species arguing from the weathered surface that it possessed four spiracles and an anispiracle. This is in accord with the diagnosis of *Rhopaloblastus* and with the species described below but *C. casei* Brown, 1942 has yet to be re-examined to verify this feature and determine whether it should remain in that genus. Radials of this new species closely resemble radials ascribed to *Rhopaloblastus* (?) *belfordi* (Crockford & Brown) (Brown,1942:102) from the Permian of the Hunter Valley and to *Rhopaloblastus*? cf. *belfordi* (McKellar,1969:25) from the Berserker Beds near Rockhampton. Without knowledge of the anal deltoids it is impossible to assign these isolated radials generically; their elongate ambulacra indicate *Calycoblastus* but the similarity to those assigned to *Rhopaloblastus* below suggest the earlier assignments may be correct. It is surprising that no reference was made to *Calycoblastus* in discussions of these eastern Australian radials by either author.

Rhopaloblastus cuspidus sp. nov.
(Figs 29,30)

ETYMOLOGY

Latin *cuspis*, point; refers to adoral projection of radial at centre of ambulacra.

MATERIAL

Holotype QMF21519; paratypes articulated specimens QMF21519, 21521, and NMVP94182, basals QMF21523, 21525-21527, radials QMF21524, 21528-21530, 21532-21537, and lancets QMF21520, 21522, 21531 from QML757.

DESCRIPTION

Calyx tall, with height to width ratio 2, maximum width at aboral extremities of ambulacra which are 0.3 of height from oral pole; vault dome-shaped. Pelvis conical, with relatively broad base (2mm), at least at calical height of about 20mm. Stem unknown.

Basals three, approximately half pelvic height, each occupying 120° of circumference, slightly waisted just above stem attachment, with straight flaring sides; upper margin concave to chevron-shaped centrally, descending on both sides. Stem attachment area terminal, flat to gently concave, with narrow marginal crenullarium. Radials tall, occupying about half calical height, with well developed comarginal growth ridges in each growth sector, externally convex in both transverse and vertical section, with broad low tubercle at origin a short distance below the aboral end of ambulacral sinus, with a low ridge extending over that short distance and the ridge waisted at its midlength. As the ridge widens towards the ambulacrum it merges with a narrow smooth area of secondary calcite deposition bordering the ambulacral sinus under which growth lines of the RR sector simply disappear. At the aboral end of the ambulacral sinus a short broad cusp projects orally (often broken off on available material but if not evident, the broken base is evident). Ambulacral sinus of variable length but usually occupying about half length of radial (almost all dissociated radials are broken in the RD sector, making it impossible to be certain of this proportion but in some radials the length of the RB sector relative to its width suggests that the ambulacral sinus may occupy less than 20% of radial length). Ambulacra narrow, widening only gently adorally, depressed beneath outer surface of radial; lateral walls of ambulacral sinus becoming higher towards RD front, gently convex, crossed at low angle to lateral margins by growth ridges that are coarser than on the exterior, sigmoidal in section with variable attitude from almost vertical and then the sigmoidal section only weakly evident to much lower angle exposing a stronger sigmoidal section and producing a much wider ambulacral sinus; in the latter case the groove formed by the sigmoidal wall of the sinus is closer to the external surface than the convex roll and the groove does not reach the aboral end of the sinus. On the floor of the ridges is a further groove to accommodate the lancet plate; lancet extremely long, subquadrate in section, covered by side plates. Side plates each with single large prominent brachiolar facet and hydrospire pore abradially between successive side plates; side plates in contact along radial line throughout ambulacrum. RD margin variably transverse to chevron-shaped orally, and either straight or slightly sigmoidal, overlying part of deltoid; some isolated radials appear to have pointed limbs suggesting the RD margin could, in that case, be rather short but articulated specimens of that type are unknown. On the radial interior secondary calcite near the aboral end of the ambulacrum has weathered away in some specimens exposing the hydrospires in groups of 5.

Deltoid with tall triangular aboral part bearing a median radial crest and prominent transverse coarse growth ridges that run aborally down the wall of the ambulacral sinus; oral end expanded into large deltoid lip around the spiracle opening which descends at a low angle beneath the triangular part of the deltoid. Around the spiracle and extending down the deltoid-ambulacrum boundary are small upright spiracle cover plates. Anal deltoid area destroyed by compaction in holotype but a superdeltoid is evident with low ridged radial ornament on it in a dislocated situation. On paratype theca (Fig.29E,F) the exposed cryptodeltoids are evident with weathered remnants of the hypodeltoid also apparent. Oral opening pentagonal.

Remarks

The complete holotype and paratype (Fig.29D-F) provide most of the critical information on arrangement of plates in the theca. In the holotype, features may not be directly interpreted because of compaction after death which has apparently shortened the polar axis and probably increased its diameter. Most isolated plates available are incomplete or crushed but all in all a fairly good idea of the species is available.

This species is distinguished by its thecal and ambulacral shapes and has the unique feature of the cusp in the aboral end of the ambulacral sinus. The prominent growth lines across the deltoid also appear to be distinctive.

Class ECHINOIDEA
Subclass REGULARIA Latreille, 1825
Order CIDAROIDA Claus, 1880

Cidaroid indet.
(Fig.31)

Material

Spine bases QMF21541-21543 and fragmentary interambulacral plates QMF21544-21552 all from the type section of the Callythara Formation (QML761).

Remarks

Teichert (1951:80) reported that echinoids are quite unknown in the Permian of Western Australia and none have been described since then. In washed samples from the type locality of the Callytharra Formation fragments of echinoids have been found and are reported here to make the faunal list more comprehensive.

The primary tubercles on these interambulacral plates are typically cidaroid with their prominent boss, platform, and tubercle.The noncrenulate tubercles along with the long, solid spines with longitudinal ridges suggest the Archaeocidaridae but the Miocidaridae cannot be excluded so family assignment is not attempted. Although different stages of weathering could be inducing different appearances of the plate ornament away from the tubercles it seems highly likely that at least 2 different types are present. Therefore, the possibility should be kept in mind that more than one species is present.

Archaeocidaris selwyni Etheridge,1892 from the Permian of NSW so the group is known from Australia but that species had much larger interambulacral plates than are available from the Western Australian sample. Although these species are probably closely related useful comparison is not possible at present.

Class STELLAROIDEA Lamarck, 1801
Family MONASTERIDAE Schuchert,

Monaster Etheridge,1892

Type Species

Palaeaster clarki deKoninck, 1877 from the Permian of New South Wales; designated Schuchert,1914.

Monaster coleyi sp. nov.
(Fig.32)

Etymology

For the collector Mr J. Coley who was bookkeeper at Wandagee Station for many years.

Material

Holotype NMVP127200 and paratype NMVP127201 from the Wandagee Beds (horizon q-r), on the north bank of the Minilya River in the eastern limb of the syncline near Coolkilya Pool. Collected by J. Coley. From the collections of C. Teichert deposited in the University of Melbourne and transferred to the Museum of Victoria in the early 1980s.

Description

This species is described by comparison with *Monaster wandageensis* Kesling,1969.

Stellate; arms tapering gradually to nearly parallel-sided; widened adorally to produce smooth curve on the interbrachial margin. Disc with prominent coronet on aboral surface; R1 subrectangular, smooth, lying over Sm2 plates and abutting Sm1 plates on adpolar corners. Plating inside Sm1 circlet unknown. Interradially and distally between Sm2 plates is a deep cleft. M large, overlapping two Sm2 and abutting two R1 plates, with subradial striae.

Oral surface flat, mouth small; Adm1 and Ax not clear.

Arms strongly plated. Amb plates small, set deep in ambulacral groove. Admm wider than long, with transversely oblique row of 3 or 4 short stout spines, with obtusely pointed margin on ambulacral groove, with abradial margin in zone of tiny plates apparently part of a shagreenate skin covering the aboral surface and terminating at the junction between Imm and Admm.

Imm longer than Admm, approximately subquadrate, with obtusely pointed adradial margin, with series of transverse flutings along abradial edge. Radials small, subquadrate proximally, becoming more rounded distally, not in contact with each other, in contact with Imm at certain points only leaving gaps at sutures between Admm. All covered by finely shagreenate skin with small plates embedded in it.

REMARKS

This species is separated from the closely related *M. wandageensis* Kesling,1969 from the same locality by its nontuberculate R1, smaller Sm1, interradial clefts between Sm2 plates, and finely shagreenate aboral skin. It differs from *M. carnarvonensis* Kesling, 1969 also from the same locality, by the subrectangular R1, larger M, less tapering arms and finely shagreenate skin. It differs from the type species in the narrower, and straighter arms and more numerous arm plates.

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LOCALITY REGISTER

QML localities are in the Callytharra Formation. Map sheets referred to are in the 1:250 000 Geological Series.

QML757 – North side of bladed track from Callytharra Homestead to Byro Homestead in western most exposures 1.5km west of type section south of Wooramel River. 25°52'30"S, 115°29'E Wooramel Sheet SG50-5, 1966.

QML758 – North side of bladed track from Callytharra Homestead to Byro Homestead as track enters dry wash tributary to Wooramel River; lowermost fossiliferous shale and marl capped by limestone in lower fossiliferous unit in Callytharra Formation. type section. 25° 52'30"S, 115° 30'05"E, Glen burgh Sheet SG50-6, 1963.

QML759 – Second fossiliferous shale and marl capped by limestone in type section. South side of track and stratigraphically higher than QML758.

QML760 – Third fossiliferous shale and marl capped by limestone in type section. Immediately south of and stratigraphically higher than QML759.

QML761 – Fourth and fifth fossiliferous shale and marl capped by limestone in type section. Immediately south and stratigraphically higher than QML760.

QML767 – Flats south of low hill approximately 100-150m northeast of turnoff to Merlinleigh Homestead, 6.5km west northwest of Mt Sandiman Homestead. 24° 23'S, 115° 20'E, Kennedy Range Sheet SG50-1, 1963.

QML768 – Flats with low limestone exposures 50-100m east of new road to Moogoorie on both sides of northeast-southwest fenceline, 24° 18'57"S, 115° 18'40"E, Kennedy Range Sheet SG50-1, 1963.

QML770 – 2-3km east of Mundarrie Well in limestones of west dipping hogbacks north and south of Carnarvon-Lyndon road; GR292356, Winning Pool - Minilya Sheet SF50-13, 49-16, 1984.

QML771 – Third massive sandstone above base of Wandagee Formation, 50-150m north of Minilya River in east limb of syncline; GR257375, Winning Pool-Minilya Sheet SF50-13, 49-16, 1984.

QML772 – Bench in lower slope below cliff 0.5-1.0km NNW of type section in Cherrabun Member of

Hardman Formation, Millyit Range; GR767877 Crossland Sheet SE51-16, 1977.

BMRloc. KNF73 – Noonkanbah Formation (type section) at Brutens Yard.

BMR loc. ML87 and ML89 – Bulgadoo Shale, lowermost fossiliferous horizon; campsite east of Mia Mia Homestead. 23° 21'S, 114°34'E.